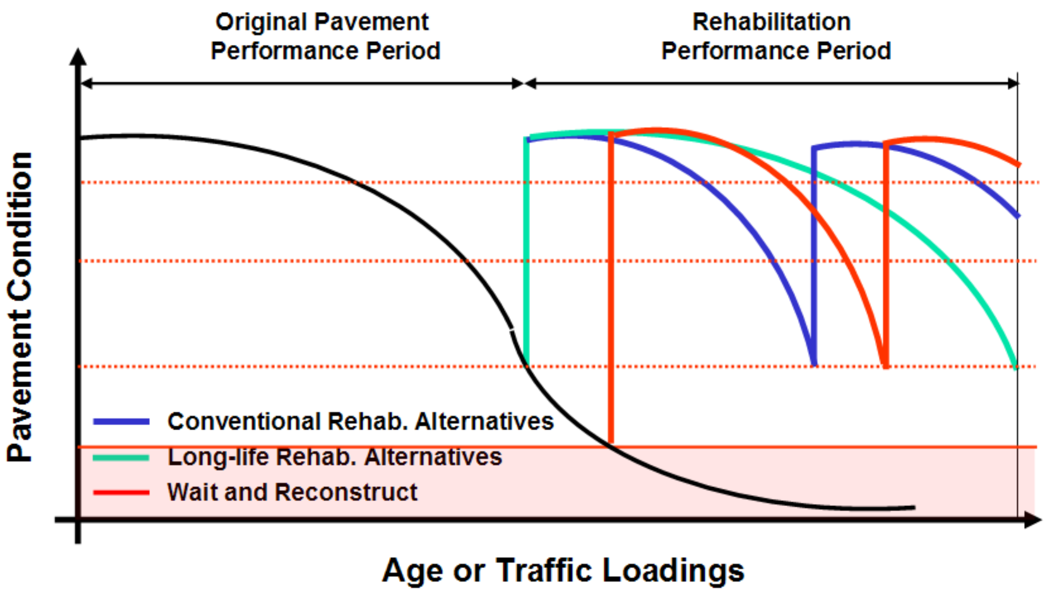
INTERIM
LIFE-CYCLE COST ANALYSIS PROCEDURES MANUAL



Note to the User

To use this manual, the reader must have Life-Cycle Cost Analysis software program *RealCost, Version 2.2.1*. The program can be downloaded from

http://www.dot.ca.gov/hq/esc/Translab/OPD/DivisionofDesign-LCCA.htm

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State of California
Department of Transportation
Pavement Standards Team & Division of Design

DISCLAIMER

This interim manual is intended for the use of Caltrans and non-Caltrans personnel on projects on the State Highway System regardless of funding source. Engineers and agencies developing projects off the State Highway System may use this interim manual at their own discretion. Caltrans is not responsible for any work outside of Caltrans performed by non-Caltrans personnel using this interim manual.

ACKNOWLEDGMENT

The information contained in this interim manual is a result of efforts of many individuals in the Department of Transportation, Pavement Standards Team, Division of Design, and the University of California, Partnered Pavement Research Center. Questions regarding this interim manual should be directed to Manas Thananant at (916) 227-5839 or manas_thananant@dot.ca.gov.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1 - INTRODUCTION

1.1 Purpose of This Manual

This manual describes life-cycle cost analysis (LCCA) procedures to be used on pavement projects on the State Highway System, regardless of funding source. The manual provides step-by-step instructions for using *RealCost*, a computer software program developed by the Federal Highway Administration (FHWA). *RealCost* was chosen by Caltrans as the official software for evaluating the cost effectiveness of alternative pavement designs for new roadways and for existing roadways requiring CApital Preventive Maintenance (CAPM) rehabilitation or reconstruction. This manual describes in detail how to perform an LCCA in order to assure that the project alternatives are analyzed objectively and consistently statewide, regardless of who designs, builds, or funds the project.

1.2 Background

LCCA is an analytical technique that consists of well-founded economic principles to evaluate long-term alternative investment options. The analysis enables total cost comparison of competing design alternatives with equivalent benefits. LCCA accounts for relevant costs to the sponsoring agency, owner, operator of the facility, and the roadway user that will occur throughout the life of an alternative. Relevant costs include initial construction (including project support), future maintenance/rehabilitation, and user costs. This analytical process helps to identify the lowest cost option to accomplish the project and provides other critical information for the overall decision-making process. The lowest cost option may not ultimately be selected after such considerations as available budget, risk, political, and environmental concerns are taken into account.

1.3 Caltrans' Policy

The FHWA encourages the use of LCCA in analyzing all major investment decisions to increase the efficiency and effectiveness of those decisions. It is Caltrans' policy that life-cycle cost impacts are fully taken into account when making project-level decisions for pavements[1].

Life-cycle cost analysis must be performed using the procedures and data of this manual for all projects on the State Highway System, which include pavement work, regardless of funding source. Life-cycle cost analysis is not required for the following projects or type of pavement:

- Major maintenance (HM-1)
- Minor A and Minor B
- Permit Engineering Evaluation Reports (PEER)
- Maintenance pullouts
- Landscape paving

For the above exempted projects, the project manager and the project development team will determine on a case-by-case basis if a life-cycle cost analysis should be done and how it should be documented for each project development phase.

When the alternative with the lowest life-cycle cost is not selected, the reasons why not must be documented. Procedures for how to document life-cycle costs in project documents can be found in Appendix O-O of the Project Development Procedures Manual (PDPM).

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[1] See Memorandum "Use of Life Cycle Cost Analysis for Pavements" by Richard Land, Chief Engineer dated March 7, 2007.

Pavement work is considered to include all the work associated with providing material and constructing a pavement structure, including subbase, base, surfacing, and pavement drainage. It can consist of constructing, widening, rehabilitating, or overlaying lanes, shoulders, gore areas, intersections, or parking lots, and other similar activities.

This manual is intended to provide the procedures and tools to implement these policies. This manual will be updated with new data and information as needed. Additional information can be found in the Project Development Procedures Manual Chapter 8 and the Highway Design Manual, Topics 612 and 619. Where conflicts in information or requirements may exist or are perceived to exist, the information in this manual shall supercede the information in the Project Development Procedures Manual and Highway Design Manual.

The Highway Design Manual (HDM) Topics 612 and 619 identify situations where an LCCA must be performed to assist in determining the most appropriate alternative for a project by comparing the life-cycle costs of different:

1) Pavement types (flexible, rigid, or composite);
2) Rehabilitation strategies;
3) Pavement design lives (e.g., 5 vs. 10 years, 10 vs. 20 years, 20 vs. 40 years, etc.); and
4) Implementation strategies (combining widening and rehabilitation projects vs. building them separately).

If a change in pavement design alters the pavement design life or other performance objectives during the design of the project, the LCCA must be updated.

CHAPTER 2 - LCCA METHODOLOGY

Once a decision has been made to undertake a project, a life cycle cost analysis (LCCA) should be conducted as early as possible in the project development process. Caltrans practice is to perform an LCCA when scoping a project (Project Initiation Document phase) and again during the Project Approval & Environmental Document phase (PA&ED). There are two different approaches in life-cycle cost computation: deterministic and probabilistic. The deterministic approach is the traditional methodology in which the user assigns each LCCA input variable a fixed, discrete value usually based on historical data and user judgment. The probabilistic approach is a relatively new methodology and accounts for the uncertainty and variation associated with input values. The probabilistic approach allows for simultaneous computation of differing assumptions for many variables by defining uncertain input variables with probability distributions of possible values. Currently at Caltrans, probability distribution functions for individual LCCA input variables are still under development and are not yet available for use. **Therefore, Caltrans only uses the deterministic approach at this time.**

The steps for performing an LCCA are:

1) Establish alternatives;
2) Determine an analysis period;
3) Determine a discount rate;
4) Determine maintenance and rehabilitation frequencies;
5) Estimate costs;
6) Calculate life-cycle costs; and
7) Analyze alternatives.

The LCCA procedures described herein were derived from the FHWA's *RealCost User Manual* (2004) and *LCCA Technical Bulletin* (1998), "Life-Cycle Cost Analysis in Pavement Design," and the *Life-Cycle Cost Analysis Primer* (2002). These can be accessed from the Caltrans Website at http://www.dot.ca.gov/hq/esc/Translab/OPD/DivisionofDesign-LCCA.htm. The additional tables, figures, and other resources included in this manual are specifically developed for Caltrans projects to guide the data inputs needed for running *RealCost*.

2.1 Establishing Alternatives

LCCA begins with the development of alternative pavement designs that will accomplish the structural and performance objectives for a project. For example, comparisons can be made between flexible vs. rigid pavements; rubberized asphalt concrete (RAC) vs. conventional hot mixed asphalt (HMA) pavements; HMA mill-and-overlay vs. HMA overlay; and 10-year vs. 20-year design life rehabilitations. Each competing alternative must be a properly designed, viable pavement structure that would be approved for construction if selected.

When selecting design alternatives for the LCCA, the following provisions must be met:

1) When comparing alternate design lives for pavements, at least two of the alternatives must have the same pavement surface [i.e. HMA, RAC, jointed plain concrete pavement (JPCP)]. Exceptions to this provision would include situations where no standard design with an alternate design life exists for the pavement surface in question. [Examples: no standard flexible pavement design for a Traffic Index (TI) > 15; no continuously reinforced concrete pavement (CRCP) designs for High Mountain or High Desert climate regions].

2) RAC must be included as an alternative when a flexible pavement is being considered and there is not a justified reason that RAC is not viable for the location. If RAC is not viable, the reasons must be included in the Project Initiation Document (PID) and Project Report (PR). When comparing HMA with RAC, be sure that both alternatives either include or do not include OGFC /RAC-O. For further information on when and how to use RAC, see the HDM Index 631.3 and the Asphalt Rubber Usage Guide.

3) When writing a PID, the LCCA must at least determine which alternate pavement design life is the most cost effective. Caltrans currently investigates the following alternate pavement design lives:

   - 5-year (CAPM projects only)
   - 10-year
   - 20-year
   - 40-year
   - Remaining Service Life for adjacent roadway (For widening projects only)

   The HDM Topic 612 provides the minimum requirements for which pavement design lives to use for each type of project. The most difficult pavement design life to determine is the one for remaining pavement service life of adjacent roadway (RSL). RSL is determined by estimating how much life the existing pavement that adjoins the widening project has before a CAPM project is needed. RSL is determined by the District Maintenance Engineer or District Materials Engineer (DME) by estimating (in 5 year increments) how much life is left in the existing pavement that adjoins the widening project before a CAPM project is needed. Note that per the HDM Index

612.3, the pavement design life of the widening cannot be less than the design period (HDM 103.2) of the project. That means that if the existing pavement on a widening project has an estimated remaining service life of 15 years and the design period for the widening project is 20 years, then the pavement design life for the widening project and the RSL value to use for the LCCA is 20 years.

4) Ideally, the type of pavement surface (flexible vs. rigid vs. composite, HMA vs. RAC, JPCP vs. CRCP) should also be determined during the PID phase. Rehabilitation and CAPM projects can typically be determined during the PID phase. However, for new construction or widening, because information is often limited during the PID phase, determination of the pavement surface type can be deferred until the PA&ED phase. If a preliminary decision for pavement type has been made during the PID phase, validity of that decision should be checked and verified during the PA&ED phase. If a pavement surface determination cannot be made at the PID phase and construction dollars are being programmed with the PID document, then the pavement costs should be determined as follows:

   a) For widening, select the same pavement type as the existing (flexible, rigid, or composite), except when the TI > 15, use composite pavement in lieu of flexible pavement. This is because Caltrans currently does not have a flexible pavement design for TI > 15.

   b) If flexible is the expected alternative, assume the surface type is RAC.

   c) For new construction, assume flexible pavement if the TI $\leq$ 10, and rigid or composite pavement if the TI $\geq$ 14. If the TI > 17, assume CRCP as the preferred rigid pavement alternative. Between TI values of 10 and 14, the engineer should select the alternative that best fits the situation. Historically, Caltrans has used rigid pavement on freeways, expressways, and flexible pavement on conventional highways. If unsure, which alternative fits the situation, the alternative with the higher initial cost can be selected.

5) For new construction projects with a 20-year TI > 10, an LCCA analysis comparing rigid/composite and flexible pavement alternatives must be done at the PA&ED phase.

6) The alternatives being evaluated should have identical improvements. For example, comparing 10-year vs. 20-year rehabilitations or new construction of flexible vs. rigid pavements are identical improvements. Comparing lane replacement vs. overlay is also an identical improvement. Conversely, comparing pavement rehabilitation to new construction, pavement overlay to pavement widening, or whether to do pavement rehabilitation at location 1 or location 2 are not identical benefits. Projects that provide different benefits should be analyzed using a Benefit-Cost Analysis (BCA), which considers the overall benefits (safety, environmental, social, etc.) of an alternative as well as its costs. For further information on BCA, refer to the Cal-B/C (California Life-Cycle Benefit/Cost Model) user manuals and technical supplements, which are available from the Division of Transportation Planning at http://www.dot.ca.gov/hq/tpp/planning_tools/tools.htm.

Table 1 provides some alternatives that will meet the above requirements. To use the table, the following information must be determined first:

1) The type of pavement project. Pavement project types are divided into 4 categories: new construction, widening, roadway rehabilitation, and CAPM (pavement rehabilitation). Reconstruction, another type of pavement project, is considered equivalent to new construction. The HDM Topic 603 provides definitions for each of the projects.
2) The document that is being written, whether it is a PID, PR, or Project Scope and Summary Report (PSSR). Draft project reports are considered to be the same as project reports.
3) The condition of the project. Conditions are based on the 20-year TI (new construction), existing pavement type (for widening rehabilitation, CAPM); or, for project reports, the pavement type and design life selected in the PID.

Using the information from above, identify the line in the table the represents the project. The table provides up to three recommended alternatives (Alternatives 1, 2, and 3) for each condition and provides some additional alternatives that may be added to (or in some cases substituted for) the three recommended alternatives. Select alternatives that best suit the project conditions while still meeting the above provisions for alternative selections. Table 1 should not be viewed as a complete list of all possible alternatives that could be encountered or derived for a particular project.

Table 1
Typical Alternatives for Various Types of Projects with Pavement

Pvmt Project Type	Document	Conditions	Alt 1	Alt 2	Alt 3	Other Alternatives that could be considered		
New	**PID**	**20-yr Traffic Index (TI_{20})**						
		$TI_{20} > 15$	20-yr Rigid (JPCP)	40-yr Rigid (JPCP)	40-yr Rigid (CRCP)	20-yr Flex[1]	20-yr Composite[2]	40-yr Composite[2]
		$12 \leq TI_{20} \leq 15$	20-yr Flex[3]	40-yr Rigid (JPCP)	40-yr Flex[3]	40-yr Rigid (CRCP)	20-yr Composite[2]	40-yr Composite[2]
		$TI_{20} < 12$	20-yr Flex[3]	40-yr Rigid (JPCP)	40-yr Flex[3]	20-yr Composite[2]	40-yr Composite[2]	
	PR (PA&ED)	**PID Preferred Pvmt Type & Life**						
		Flexible (20-yr design)	Flex (HMA)	Flex (RAC)	Rigid (JPCP)	Flex (HMA w/ OGFC)	Flex (RAC-G w/ RAC-O)	Flex (HMA w/ RAC)
		Flexible (40-yr design)	Flex (HMA w/ OGFC)	Flex (RAC-G w/ RAC-O)	Rigid (JPCP)	Flex (HMA w/ RAC)	Rigid (CRCP)	
		Rigid (20-yr design)	Rigid (JPCP)	Flex (RAC)	Flex (HMA)			
		Rigid (40-yr design)	Rigid (JPCP)	Rigid (CRCP)[4]	Flex (RAC w/ RAC-O)	Composite[2]	Flex (HMA w/ RAC)	
		Composite (20-yr design)	Composite (HMA)	Composite (RAC)	Flex (HMA)	Flex (RAC)	Rigid (JPCP)	Flex (HMA w/ RAC)
		Composite (40-yr design)	Composite (HMA)	Composite (RAC)	Rigid (JPCP)	Rigid (CRCP)	Flex (RAC-G w/ RAC-O)	Flex (HMA w/ RAC)
Widening	**PID**	**Exist Road Pvmt Surface**						
		Flexible	RSL Flex	20-yr Flex	40-yr Flex	40-yr Composite[2]	20-yr Composite[2]	
		Rigid	RSL Rigid	RSL Flex	40-yr Rigid			
		Composite[6]	RSL Composite	20-yr Flex	40-yr Composite	20-yr Composite	RSL Flex	
	PR (PA&ED)	**PID Preferred Pvmt Type & Design Life**						
		Flexible ($\leq$ 20-yr design)	HMA	HMA w/ RAC	RAC	HMA w/ OGFC	RAC-G w/ RAC-O	
		Flexible (> 20-yr design)	HMA w/ RAC	RAC-G w/ RAC-O	HMA w/ OGFC			
		Rigid ($\leq$ 20-yr design)	Rigid	Flex (RAC)	Flex (HMA)			
		Rigid (> 20-yr design)	Rigid			Flex (RAC-G w/ RAC-O)	Flex (HMA w/ OGFC)	
		Composite[6] ($\leq$20-yr design)	Composite (HMA)	Composite (RAC)	Flex (RAC)	Flex (HMA)	Rigid	
		Composite[6] (>20-yr design)	Composite (RAC)	Flex (RAC-G w/ RAC-O)	Flex (HMA w/ OGFC)	Composite (HMA)		
CAPM	**PR**	**Exist Road Pvmt Surface**						
		Flexible	HMA	RAC		Seals[5]		
		Rigid (< 5% slab replacement)	Grinding (Rigid Strategy)	Thin RAC Overlay				
		Rigid ($\geq$ 5% slab replacement)	Grind & Slab Replacements	Lane Replacement (Rehab Strategy)				
		Composite[6]	Use Flexible CAPM Alternatives					
Roadway Rehabilitation	**PSSR**	**Exist Road Pvmt Surface**						
		Flexible	HMA	RAC		HMA w/ OGFC	RAC-G w/ RAC-O	
		Flexible w/ OGFC or RAC-O	HMA w/ OGFC	RAC-G w/ RAC-O				
		Rigid	10-yr Crack, Seat & Flex Overlay	20-yr Crack, Seat & Flex Overlay	40-yr Lane Replacement	20-yr Lane Replacement	40-yr Crack, Seat & Flex Overlay[1]	
		Composite[6]	10-yr Overlay	20-yr Overlay	40-yr Lane Replacement	20-yr Lane Replacement		

Notes:
* Refer to Appendix 1, "Glossary and List of Acronyms" for definitions of terms used in the table.
(1) Highway Design Manual (HDM) currently does not provide a methodology for this design. Consult the Office of Pavement Design for special design options.
(2) Composite Pvmt may be thin Flex ($\leq$ 0.25') over JPCP or CRCP. Choose the same rigid pvmt type that is being analyzed for one of the other alternatives. Assume RAC for flexible surface unless it is desired to analyze both RAC and HMA alternatives or RAC is not viable (see HDM 631.3)
(3) Assume RAC unless there are specific reasons RAC cannot be used. Document these reasons in Project Initiation Documents. If sufficient information is available, can opt to analyze HMA vs RAC in addition to rigid pavement alternatives.
(4) Consider only for $TI_{20} \geq 12$.
(5) Requires agreement with HQ & District Program Advisor
(6) Includes previously built crack, seat, and Flexible overlay projects

2.2 Determining an Analysis Period

The *analysis period* is the period of time during which the initial and any future costs for the project alternatives will be evaluated. Table 2 provides the common analysis periods to be used when comparing alternatives of a given design life or lives. For example, a minimum analysis period of 35 years should be used if 10-year and 20-year design life alternatives are compared, or if two different design alternatives with the same 20-year design life are compared.

Table 2. LCCA Analysis Periods

Alternative Design Life	5-Yr	10-Yr	15 or 20-Yr	25 to 40-Yr
5-Yr	20 years	20 years		
10-Yr	20 years	20 years	35 years	55 years
15 or 20-Yr		35 years	35 years	55 years
25 to 40-Yr		55 years	55 years	55 years

LCCA assumes that the pavement will be properly maintained and rehabilitated to carry the projected traffic over the specified analysis period. As the pavement ages, its condition will gradually deteriorate to a point where some type of maintenance or rehabilitation treatment is warranted. Thus, after the initial construction, reasonable maintenance and rehabilitation (M&R) strategies must be established for the analysis period. Figure 1 shows the typical relationship between pavement condition and pavement life when appropriate maintenance and rehabilitation strategies are applied in a timely manner.

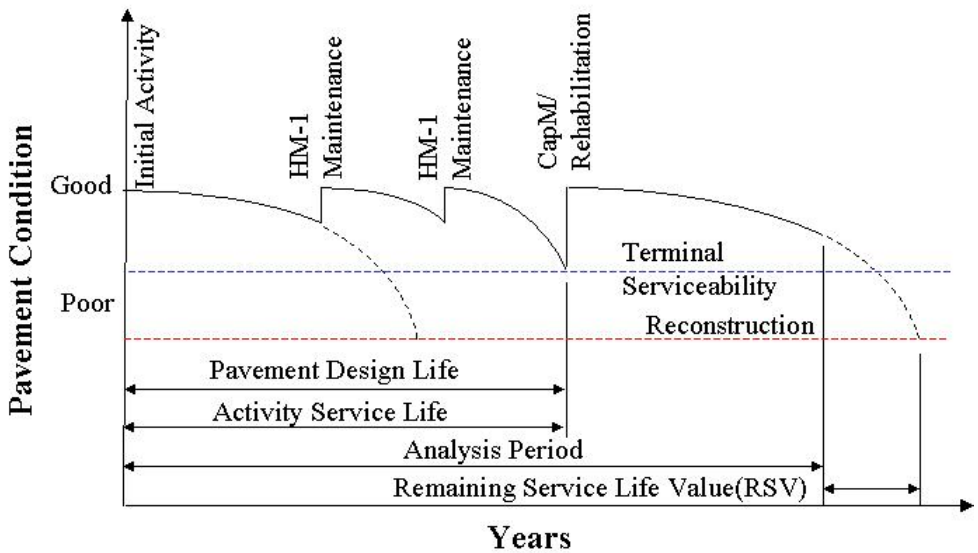


Figure 1. Pavement Condition vs. Years
Note: see Appendix 1, "Glossary and List of Acronyms" for definitions of terms used in the figure.

Information on pavement performance and M&R strategies for various types of pavements are discussed further in Section 2.4, "Determining Maintenance and Rehabilitation Frequencies."

2.3 Determining a Discount Rate

Discount rate is the interest rate by which future costs (in constant dollars) will be converted to present value. It is commonly known as a "real discount rate" as it reflects only the true time value of money without including the general rate of inflation. Real discount rates typically range from 3 percent to 5 percent, representing the prevailing interest rate on borrowed funds less inflation. **Caltrans currently uses a discount rate of 4 percent in the LCCA of pavement structures.**

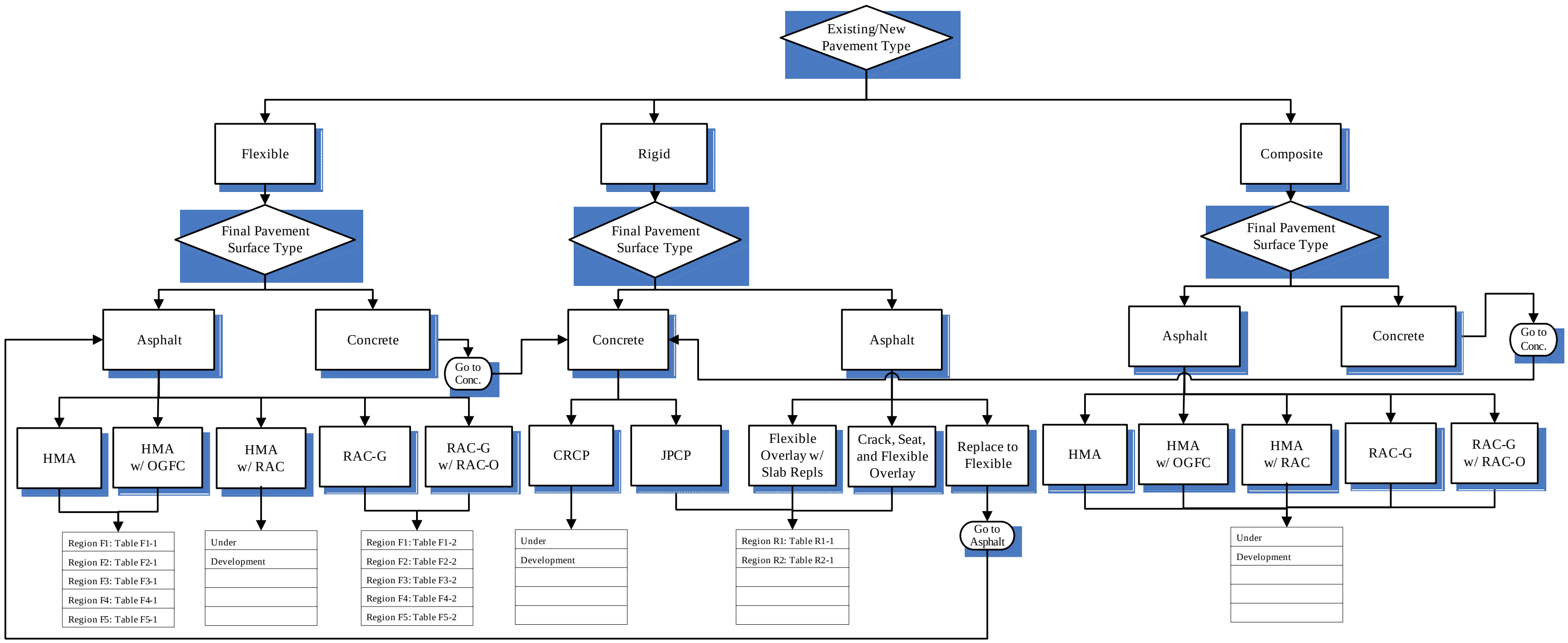
2.4 Determining Maintenance and Rehabilitation Frequencies

After the viable project alternatives are identified, a follow-up pavement M&R schedule for each alternative must be determined. Pavement M&R schedule typically identifies the sequence and timing of future treatment activities that are required to maintain and rehabilitate the pavement over the analysis period. Pavement M&R schedules found in Appendix 4 of this manual are to be used in the LCCA for pavement projects on the State Highway System.

To find an applicable pavement M&R schedule for a project alternative in Appendix 4, the following information needs to be determined:

1) *Existing/New Pavement Type.* The types are: flexible, rigid, and composite.
2) *Final Pavement Surface Type*. The final pavement surface type is the alternative being investigated for LCCA. Options include HMA, HMA with Open Graded Frictional Course (OGFC), RAC Gap Graded (RAC-G), or RAC Gap Graded with RAC Open Graded (RAC-G w/RAC-O), JPCP, and CRCP.
3) *Pavement Design Life.* See the HDM Topic 612 for guidance.
4) *Pavement Climate Region*. This is obtained from the map in Figure 17, which is also available on the Pavement Engineering web page at http://www.dot.ca.gov/hq/oppd/pavement/pdindex.htm.
5) *Maintenance Service Level (MSL)*. MSL is the state highway classification used by the Division of Maintenance for maintenance program purposes. Refer to Appendix 1, "Glossary and List of Acronyms," for further definition of MSL.

Once all the above information is known, refer to Figure 2, to find the appropriate pavement M&R schedule table in Appendix 4. Then, select the applicable schedule based upon the project alternative type (new construction/reconstruction, CAPM, or rehabilitation), final pavement surface type (HMA, HMA w/ OGFC, JPCP, etc.), pavement design life, and maintenance service level of the roadway. In cases where two optional schedules (option 1 and option 2) are provided, either option may be selected for the analysis if the same option is selected for each alternative.



Region F1: Coastal Climate Region **Region F2:** Inland Valley Climate Region **Region F3:** Desert Climate Region **Region F4:** Low Mountain & South Mountain Climate Regions **Region F5:** High Mountain & High Desert Climate Regions	**Region R1:** Coastal, Inland Valley, Desert, and Low Mountain & South Mountain Climate Regions **Region R2:** High Mountain & High Desert Climate Regions

Figure 2. Pavement M&R Schedule Determination Flow Chart

Figure 3 shows an example of pavement M&R schedules found in Appendix 4 for RAC pavements in the State's "coastal" climate region. These typical schedules are derived from the "Pavement M&R Decision Trees" prepared by each Caltrans district and experience with pavement performance in California (*Note*: these schedules assume there will be no early failures). As shown in the figure, they include only the future CAPM, rehabilitation, or reconstruction activities. They should be entered into *RealCost* as future rehabilitations in the same sequence. Within the analysis period selected, *RealCost* allows the user to enter up to six future rehabilitation activities following the initial construction of project alternative. Interim maintenance treatments such as Major Maintenance (HM-1) projects and work by maintenance field crews performed between each scheduled activity have been converted into an annualized maintenance cost ($/lane-mile), which is entered separately into *RealCost*, as discussed further in Section 2.5.2, "Maintenance Costs" and in Section 3.3, "Alternative-Level Inputs."

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year	0	5	10	15	20	25	30	35
CapM												
RAC	5	1,2		Year of Action	0	9		19		28		
				Activity Description	RAC CapM (5 yr)	RAC Rehab (10 yr)		RAC CapM (5 yr)		RAC Rehab (10 yr)		
				Activity Service Life (years)	9	10		9		10		
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	0	3,915		4,270		3,915		
		3		Year of Action	0	9		18		27		
				Activity Description	RAC CapM (5 yr)	RAC CapM (5 yr)		RAC CapM (5 yr)		Reconst. (20 yr)		
				Activity Service Life (years)	9	9		9		20		
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	0	4,270		4,270		1,167		
	10	1,2		Year of Action	0		10					35
				Activity Description	RAC CapM (10 yr)		RAC Rehab (20 yr)					RAC CapM (10 yr)
				Activity Service Life (years)	10		25					10
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,915		3,530					3,915
		3		Year of Action	0		10					35
				Activity Description	RAC CapM (10 yr)		RAC Rehab (20 yr)					RAC CapM (10 yr)
				Activity Service Life (years)	10		25					10
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,915		3,530					3,915

Figure 3. Example of Pavement M&R Schedules

Suppose that one of the project flexible pavement alternatives being considered is a “5-year CAPM w/ RAC-G” located in the coastal climate region and with the maintenance service level of 2. The corresponding pavement M&R schedule (highlighted in gray in Figure 3) shows that the project alternative (shown as “5-year CAPM w/ RAC-G” at year 0) will last up to 9 years with periodic HM-1 maintenances. The annualized cost for the HM-1 maintenances is estimated at $4,270 per lane-mile. The pavement M&R schedule calls for “10-year Rehab” at year 9, which is expected to last up to 10 years with an annualized maintenance cost of $3,915 per lane-mile. If the analysis period is set at 20 years, the *RealCost* inputs will be “5-year CAPM w/ RAC-G” for “Initial Construction,” “10-year Rehab” at year 9, and “5-year CAPM” at year 19 for “Rehabilitation 1” and “Rehabilitation 2,” respectively.

2.5 Estimating Costs

Life-cycle costs include agency costs and user costs. Agency costs include initial, maintenance, rehabilitation (including CAPM), and remaining service life value costs. User costs include travel time and vehicle operating costs (excluding routine maintenance) incurred by the traveling public.

2.5.1 Initial Costs

Initial costs include estimated construction costs as well as project support costs (for design, environment, construction administration and inspection, project management, etc.) to be borne by an agency for implementing a project alternative.

2.5.1.1 Construction Costs: For each alternative, construction costs should be determined from the engineer’s estimate. Costs for mainline and shoulder pavement, base and subbase, drainage, joint seals, earthwork, traffic control, time-related overhead, mobilization, supplemental work, and contingencies should be included. Construction costs common to both alternatives — such as bridges, traffic signage, and striping — may be excluded if those costs can be separated from the rest of the estimate. If not, then it will be easier to include them. See the PDPM for information and work sheets for estimating costs in the PID and the PR.

2.5.1.2 Project Support Costs: Costs for project support should be decided based on the costs identified in the proposed work plan for a project alternative. When the work plan data is not yet available, use the project support cost multipliers shown in Table 3 with the initial construction costs to estimate project support costs for a project alternative.

Table 3. Agency Project Support Cost Multipliers

Type of Project		Range of Project ($)	Multiplier w/ Right-of-Way	Multiplier w/o Right-of-Way
New Construction	Small	750,000 - 5,000,000	0.47	0.39
	Medium	5,000,001 - 20,000,000	0.31	0.29
	Large	20,000,001 - 35,000,000	0.25	0.23
	Very Large	35,000,001 - Up	0.24	0.20
Widening	Small	750,000 - 2,500,000	0.56	0.52
	Medium	2,500,001 - 5,000,000	0.39	0.35
	Large	5,000,001 - 15,000,000	0.28	0.26
	Very Large	15,000,001 - Up	0.25	0.24
CAPM	Small	750,000 - 2,000,000	0.19	0.19
	Medium	2,000,001 - 5,000,000	0.18	0.15
	Large	5,000,001 - Up	0.16	0.13
Roadway Rehabilitation	Small	750,000 - 2,000,000	0.35	0.31
	Medium	2,000,001 - 5,000,000	0.28	0.26
	Large	5,000,001 - Up	0.20	0.19

* Refer to Appendix 1, "Glossary and List of Acronyms" for definitions of terms used in the table.

Example:

Consider a 5-year CAPM (HMA overlay) project with an estimated construction cost (engineer's estimate) *of $4.0 million. Corresponding project support cost multipliers in Table 3 for this CAPM alternative are 0.18 with right-of-way and 0.15 without right-of-way, respectively. Accordingly, the estimated initial costs for this alternative are $4.72 million ($4.0 million for construction and $0.72 million for project supports) with right-of-way and $4.6 million ($4.0 million for construction and $0.6 million for project supports) if the project does not require right-of-way.*

2.5.2 Maintenance Costs

Maintenance costs include costs for routine, preventive, and corrective maintenance, such as joint and crack sealing, void undersealing, chip seal, patching, spall repair, individual slab replacements, thin HMA overlay, etc., whose purpose is to preserve or extend the service life of a pavement. For the LCCA, use the annualized maintenance costs included in the pavement M&R schedules in Appendix 4. These annualized costs are based on the "Pavement M&R Decision Trees" prepared by each Caltrans district and historical cost data collected by the Division of Maintenance.

2.5.3 Rehabilitation Costs

In *RealCost*, *rehabilitation costs* refer to costs for future rehabilitation (including CAPM) activities scheduled to be performed after implementing a project alternative. Rehabilitation costs for a particular activity should include costs for project supports and costs for all the necessary appurtenant work for drainage, safety, and other features.

Tables 4 and 5 summarize the estimated lane-mile construction costs (excluding project support costs) of various types of CAPM and rehabilitation projects funded by Caltrans over the latest six-year period. After selecting an applicable pavement M&R schedule for the project alternative (as discussed in Section 2.4, "Determining Maintenance and Rehabilitation Frequencies"), use the tables to estimate the cost of future rehabilitation activities to be performed after implementing a project alternative. For those future rehabilitation activities whose project type is the same as the proposed project alternative, the user can assume its rehabilitation costs to be the same as the initial costs estimated for the project alternative. For example, if a proposed project alternative is a 10-year rehabilitation (HMA overlay) and the prescribed pavement M&R schedule calls for another 10-year rehabilitation in the future, the user can use the initial costs of the project alternative as the rehabilitation costs for the repeated future activity.

Table 4. Estimated Construction Costs of Typical M&R Strategies for Flexible Pavements

Final Surface Type	Future M&R Alternative	Pvmt. Design Life (years)	$/Lane-Mile
CAPM			
HMA	HMA Overlay	5+	**99,000**
	Mill & Overlay with HMA	5+	**118,000**
HMA w/ OGFC	HMA w/ OGFC Overlay	5+	**146,000**
	Mill & Overlay with HMA w/ OGFC	5+	**165,000**
HMA w/ RAC	HMA w/ RAC Overlay	5+	**161,000**
	Mill & Overlay with HMA w/ RAC	5+	**180,000**
RAC-G	RAC-G Overlay	5+	**100,000**
	Mill & Overlay with RAC-G	5+	**119,000**
RAC-G w/ RAC-O	RAC-G w/ RAC-O Overlay	5+	**147,000**
	Mill & Replace with RAC-G w/ RAC-O	5+	**162,000**
Roadway Rehabilitation			
HMA	HMA Overlay	10	**299,000**
		20	**332,000**
	Mill & Overlay with HMA	10	**318,000**
		20	**351,000**
HMA w/ OGFC	HMA w/ OGFC Overlay	10	**346,000**
		20	**379,000**
	Mill & Overlay with HMA w/ OGFC	10	**365,000**
		20	**398,000**
HMA w/ RAC	HMA w/ RAC Overlay	10	**361,000**
		20	**394,000**
	Mill & Overlay with HMA w/ RAC	10	**380,000**
		20	**413,000**
RAC-G	RAC-G Overlay	10	**327,000**
		20	**363,000**
	Mill & Overlay with RAC-G	10	**346,000**
		20	**379,000**
RAC-G w/ RAC-O	RAC-G w/ RAC-O Overlay	10	**389,000**
		20	**422,000**
	Mill & Overlay with RAC-G w/ RAC-O Overlay	10	**408,000**
		20	**441,000**

Notes:
* Refer to Appendix 1, "Glossary and List of Acronyms" for definitions of terms used in the table.
** Lane-mile construction costs excluding project support costs

Table 5. Estimated Construction Costs of Typical M&R Strategies for Rigid Pavements

Final Pavement Type	Future M&R Alternative	Pvmt. Design Life (years)	$/Lane-Mile[1]
CAPM			
Flexible / Composite	Flexible Overlay	5+	**81,000**
	Flexible Overlay w/ JPCP Slab Replacements (with RSC 12-Hour Curing Time)	5+	**84,000**
	Flexible Overlay w/ JPCP Slab Replacements (with RSC 4-Hour Curing Time)	5+	**91,000**
Rigid - Jointed Plain Concrete Pavement (JPCP)	Conc. Pvmt Rehab A[2] (with RSC of 12-Hour Curing Time)	5+	**123,000**
	Conc. Pvmt Rehab A[2] (with RSC of 4-Hour Curing Time)		**148,000**
	Conc. Pvmt Rehab B[3] (with RSC of 12-Hour Curing Time)	5+	**88,000**
	Conc. Pvmt Rehab B[3] (with RSC of 4-Hour Curing Time)		**106,000**
	Conc. Pvmt Rehab C[4] (with RSC of 12-Hour Curing Time)	10 +/-	**82,000**
	Conc. Pvmt Rehab C[4] (with RSC of 4-Hour Curing Time)		**89,000**
Rigid - Continuously Reinforced Concrete Pavement (CRCP)	Under Development. Contact Office of Pavement Design for Assistance		
Roadway Rehabilitation			
Flexible / Composite	Flexible Overlay w/ Slab Replacements (with RSC of 12-Hour Curing Time)	10	**215,000**
	Flexible Overlay w/ Slab Replacements (with RSC of 4-Hour Curing Time)		**233,000**
	Crack, Seat, & Flexible Overlay	10	**251,000**
		20	**279,000**
	Lane Replace with Flexible	20	**941,000**
		40	**1,255,000**
	Lane Replace with Composite	20	**Under Development. Contact Office of Pvmt Design for Assistance**
		40	
Rigid - Jointed Plain Concrete Pavement (JPCP)	Lane Replacement (with RSC of 12-Hour Curing Time)	20	**1,444,000**
		40	**1,752,000**
	Lane Replacement (with RSC of 4-Hour Curing Time)	20	**1,805,000**
		40	**2,113,000**
Rigid - Continuously Reinforced Concrete Pavement (CRCP)	Lane Replacement	20	**Under Development. Contact Office of Pvmt Design for Assistance**
		40	

Notes:

* Refer to Appendix 1, "Glossary and List of Acronyms" for definitions of terms used in the table.

(1) Lane-mile construction costs excluding project support costs

(2) Conc Pvmt Rehab A involves pavement grinding, significant slab replacement, spall repair, & joint seal repair.
It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is greater than or equal to 5% and less than or equal to 7%.
For greater than 7%, the project should be scoped and analyzed as a roadway rehabilitation project.

(3) Conc Pvmt Rehab B involves pavement grinding, moderate slab replacement, spall repair, & joint seal repair.
It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is between 2 and 5%.

(4) Conc Pvmt Rehab C involves pavement grinding, minor slab replacement, spall repair, & joint seal repair.
It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is between 2% or less.
For greater than 7%, the project should be scoped and analyzed as a roadway rehabilitation project.

The following steps describe how the average construction costs in Tables 4 and 5 can be used to estimate the rehabilitation costs (to be entered as "Agency Construction Cost" in *RealCost*) for future rehabilitation activities:

1) Find the applicable pavement M&R schedule for the project alternative being considered
2) Identify the future rehabilitation activities (including CAPM and reconstruction) whose year of action falls before the end of analysis period
3) Find the applicable M&R alternative, such as "HMA Overlay," for each future rehabilitation activity ("Future M&R Alternative" column in Table 4 or 5)
4) Find the applicable lane-mile cost for each future rehabilitation activity in Table 4 or 5 based on the above information and the following:
   (a) Final surface type of future rehabilitation activity
   (b) Pavement design life of future rehabilitation activity (i.e., 5 years, 10 years, etc.)
   (c) Maintenance service level of the facility being treated
5) Multiply the total number of project lane-miles by the lane-mile cost to get the construction cost for the future rehabilitation activity
6) Determine the project support cost multiplier from Table 3 that is applicable to the calculated construction cost
7) Multiply the calculated construction cost by the project support cost multiplier to get the project support cost for the future rehabilitation activity
8) Add the construction cost and the project support cost to get the rehabilitation cost ("Agency Construction Cost").

Example:

Determine the "Activity Cost and Service Life Inputs" for future rehabilitation activities to be followed after implementing the project alternative described below:

5-year CAPM (0.15' HMA Overlay)

- *40.0 lane-miles (i.e., total project lane-miles including turn, auxiliary lane-miles) of an existing flexible pavement*
- *Agency Construction Cost: $4.6 million ($4.0 million for construction and $0.6 million for project support)*
- *Initial Construction Year: same as the first year of the analysis period*
- *Analysis Period: 20 years.*
- *Climate: South Coast*
- *Maintenance Service Level: 1*

Solution:

1) *Applicable pavement M&R schedule [from Appendix 4, Table F1-1 (2)]*

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year		0		5		10	15		20		25	30
CapM (Pavement Rehabilitation)																
HMA	5	1,2		Year of Action		0		5			15		20			
				Activity Description		CapM (5 yr)		Rehab (10 yr)			CapM (5 yr)		Rehab (10 yr)			
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	5	1,096	10	2,675		5	1,096	10	2,675		

2) *Prescribed Future rehabilitation activities (within the 20-year analysis period)*
   - (a) *10-year Rehab in year 5*
   - (b) *5-year CAPM in year 15*
   - (c) *10-year Rehab in year 20.*

3) *Applicable M&R alternative for each future rehabilitation activity (from Table 4)*
   - (a) *10-year Rehab in year 5: Mill and Overlay with HMA*
   - (b) *5-year CAPM in year 15: HMA Overlay (Note: it is assumed to be same as the initial construction)*
   - (c) *10-year Rehab in year 20: Mill and Overlay with HMA*

4) *Lane-mile costs of future rehabilitation activities (from Table 4)*
   - (a) *10-year Rehab in year 5: $299,000/lane-mile*
   - (b) *5-year CAPM in year 15: not applicable [Note: it is assumed that the rehabilitation*

costs would be same as the agency construction cost for the initial construction ($4,000K)]

(c) 10-year Rehab in year 20: same as the above 10-year Rehab in year 5

5) Construction costs for future rehabilitation activities

(a) 10-year Rehab in year 5: $11,960K (40.0 lane-miles x $299,000/lane-mile)

(b) 5-year CAPM in year 15: $4,000K Overlay (Note: it is assumed to be same as the initial construction)

(c) 10-year Rehab in year 20: same as the above 10-year Rehab in year 5

6) Project support cost multipliers for future rehabilitation activities (from Table 3)

(a) 10-year Rehab in year 5: 0.19 (for rehabilitation over $5 million w/o right-of-way)

(b) 5-year CAPM in year 15: 0.15 (for CAPM's over $2 million w/o right-of-way)

(c) 10-year Rehab in year 20: same as the above 10-year Rehab in year 5

7) Project support costs for future rehabilitation activities

(a) 10-year Rehab in year 5: $2,272K ($11,960K x 0.19)

(b) 5-year CAPM at year 15: $600K ($4,000K x 0.15)

(c) 10-year Rehab in year 20: same as the above 10-year Rehab in year 5

8) Agency construction costs for the initial construction and future rehabilitation activities

(a) 5-year CAPM in year 0: [to be entered under "Initial Construction" tab of "Alternative 1 Form" of RealCost (Figure 11)]

- *Agency Construction Cost ($1000): 4,600 ($4,000K + $600K)*
- *Activity Service Life (years): 5*
- *Maintenance Frequency (years): 1 (see Section 3.2, "Alternative-Level Inputs")*
- *Agency Maintenance Cost ($1000): 43.8 ($1,096/lane-mile x 40 lane-miles, see Section 3.3, "Alternative-Level Inputs")*

(b) 10-year Rehab in year 5: [to be entered under "Rehabilitation 1" tab of "Alternative 1 Form" of RealCost (Figure 11)]

- *Agency Construction Cost ($1000): 14,232 ($11,960K + $2,272K)*
- *Activity Service Life (years): 10*
- *Maintenance Frequency (years): 1*
- *Agency Maintenance Cost ($1000): 107.0 ($2,675/lane-mile x 40 lane-miles)*

(c) 5-year CAPM in year 15: [to be entered under "Rehabilitation 2" tab of "Alternative 1 Form" of RealCost (Figure 11)]

- *Same as the above 5-year CAPM in year 0*

(d) 10-year Rehab in year 20: [to be entered under "Rehabilitation 3" tab of "Alternative 1

Form" of RealCost (Figure 11)]
• *Same as the above 10-year Rehab in year 5.*

2.5.4 User Costs

Best-practice LCCA calls for consideration of not only agency costs, but also costs to facility users. *User costs* include travel time costs and vehicle operating costs (excluding routine maintenance) incurred by the traveling public. Such user costs typically arise when work zones restrict the normal capacity of the facility and reduce traffic flow. *User costs* are also incurred during normal operations but they are often similar between project alternatives and may be removed from most analyses. Additional user costs resulting from work zones can become a significant factor when a large queue occurs in one alternative but not in the other.

2.5.5 Remaining Service Life Value

If an activity has a service life that exceeds the analysis period, the difference is known as the *Remaining Service Life Value* (RSV). Any rehabilitation activities (including the initial construction) preceding the last rehabilitation activity will have no effective RSV at the end of the analysis period. The RSV of a project alternative at the end of the analysis period is calculated based upon total cost (agency and user costs) of the last rehabilitation activity scheduled to be done on the pavement and the percentage of service life remaining at the end of the analysis period. *RealCost* calculates the RSV of a project alternative by prorating of the total cost of the last rehabilitation activity.

2.6 Calculating Life-Cycle Costs

Calculating life-cycle costs involves direct comparison of the total life-cycle costs of each alternative. However, because dollars spent at different times have different present values, the anticipated costs of future rehabilitation activities for each alternative need to be converted to their value at a common point in time. This is an economic concept known as "discounting."

A number of techniques based upon the concept of discounting are available. FHWA recommends the present value (PV) approach, which brings initial and future costs to a single point in time, usually the present or the time of the first cost outlay. The equation to discount future costs to PV is:

$$PV = F \frac{1}{(1+i)^n} \qquad \text{(Equation 1)}$$

where
F = future cost at the end of n^{th} years
i = discount rate
n = number of years

However, the equivalent uniform annual cost (EUAC) approach is also used nationally. It produces the yearly costs of an alternative as if they occurred uniformly throughout the analysis period. The PV of this stream of EUAC is the same as the PV of the actual cost stream. Whether PV or EUAC is used, the decision supported by the analysis will be same. **Caltrans requires the LCCA results to be documented using the present value approach.**

CHAPTER 3 - USING *REALCOST*

3.1 Installing & Starting *RealCost*

3.1.1 Installation

In order to prepare a life-cycle cost estimate using *RealCost*, the software (version 2.2.1 California Edition) must first be installed. The software can be downloaded from the following web site: http://www.dot.ca.gov/hq/esc/Translab/OPD/DivisionofDesign-LCCA.htm. Follow the installation instructions provided on the web site.

> ***Note:***
>
> *Because RealCost is an add-on program designed to run in Microsoft Excel 2000 (or later), it should not require installation by Caltrans' IT staff.*

3.1.2 Start Up

Select "*RealCost* 2.2" from the Windows "Start Menu" (Programs > *RealCost* > *RealCost* 2.2) to launch the program.

When prompted for Macro options, choose "Enable Macros" to run *RealCost*. Then, open the "Input Worksheet." Immediately after the worksheet appears, the "Switchboard" panel opens on top of it (see Figure 4).

> ***Note:***
>
> *The program allows you to input date either through the "Switchboard" or directly into the Input Worksheet. This manual contains instructions for entering information by using the "Switchboard," but if one wants to directly input your values into the Input Worksheet, close the "Switchboard" by clicking the "X" in the upper right-hand corner. If one wants to restore it later, do so by clicking "RealCost" on the menu bar at the top of the window, and selecting "RealCost Switchboard."*

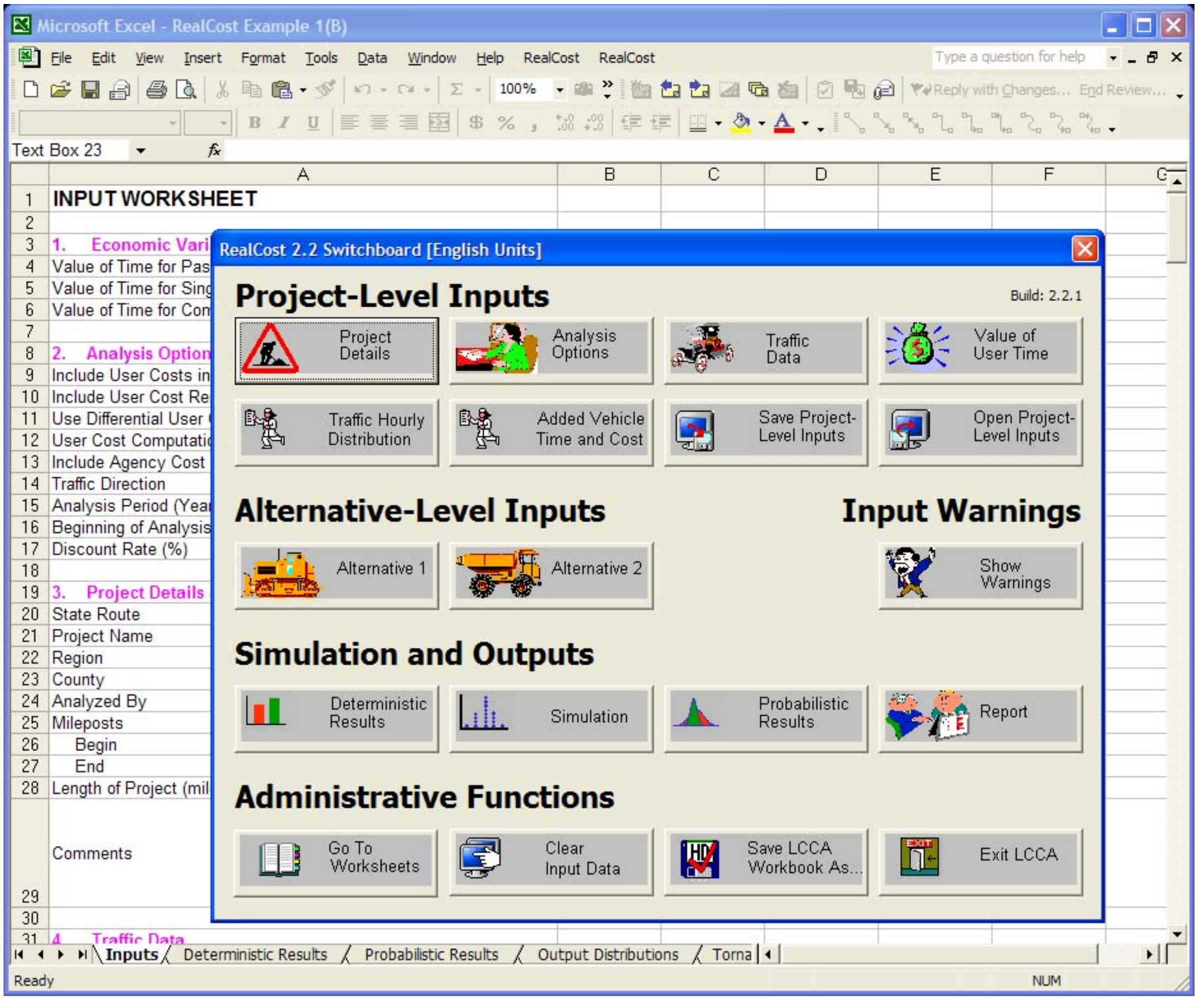


Figure 4. *RealCost* Switchboard

As Figure 4 shows, the "Switchboard" consists of five sections:

- Project-Level Inputs;
- Alternative-Level Inputs;
- Input Warnings;
- Simulation and Outputs;
- Administrative Functions.

These five items and their functions are discussed in Sections 3.2 through Section 3.5

Note:

Most of the functions available from the "Switchboard" are also accessible by selecting the "RealCost" menu item in the Microsoft Excel menu bar.

3.2 Project-Level Inputs

RealCost requires two levels of information. The first, "Project-Level Inputs," which are discussed in this section, are project-level data that apply to all the project alternatives being considered. The second information level, "Alternative-Level Inputs" (discussed in Section 3.3), is data that defines the differences between project alternatives (e.g., agency costs and work zone specifics for each alternative's component activities). To emphasize the differences between the two types of inputs, *RealCost* requires that they are entered separately.

3.2.1 Project Details

The "Project Details Form" (Figure 5) is used to enter the project documentation details. Enter the data according to the field names. Note that data entered here will not be used in the analysis. Once all the project documentation details are entered, click the "Ok" button to return to the "Switchboard" or the "Cancel" button to start over.

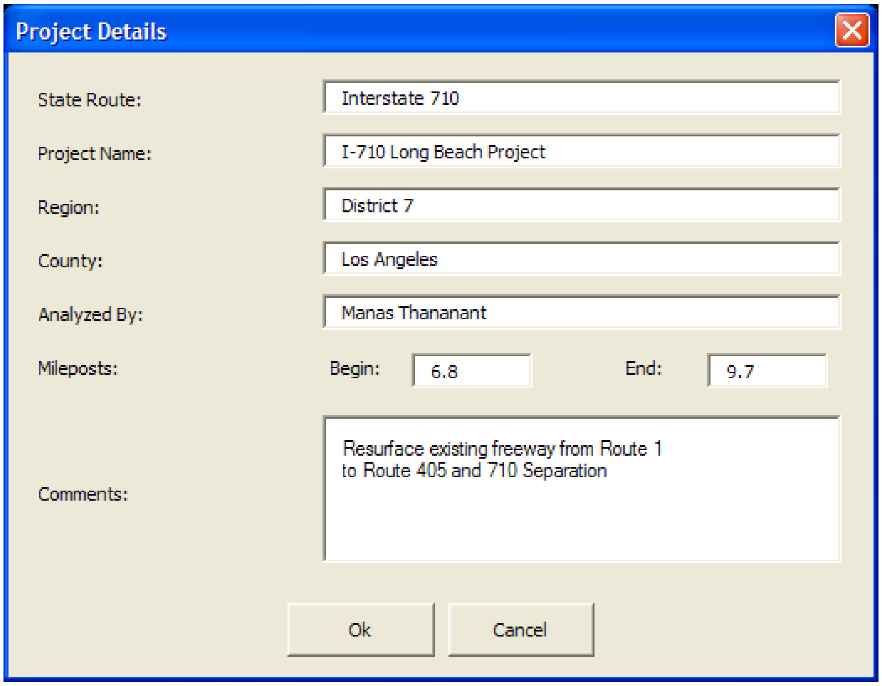


Figure 5. Project Details Form

3.2.2 Analysis Options

The "Analysis Options Form" (Figure 6) is used to define the user options that will actually be applied in analyzing the project alternatives. In this sense, this is where the actual analysis begins. The data inputs and analysis options available on this form are detailed below.

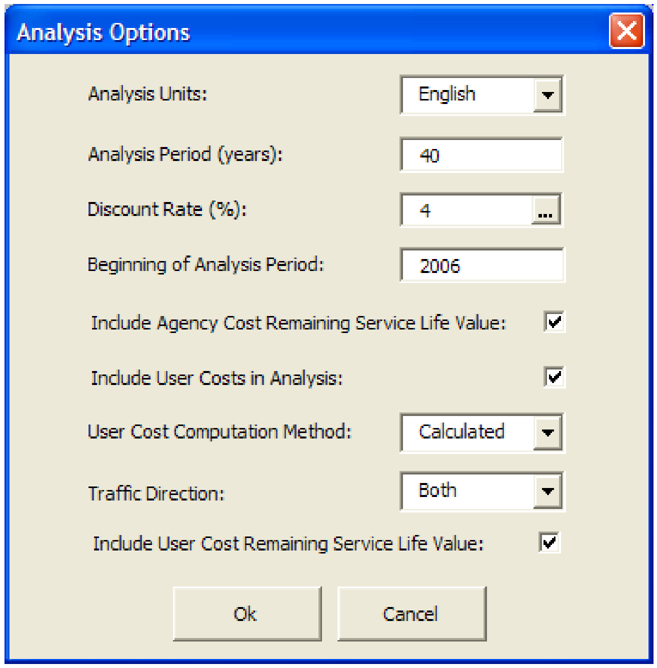


Figure 6. Analysis Options Form

- *Analysis Units*: Select either “English” or “Metric” to set the format/units for the analysis.
- *Analysis Periods (years)*: Enter an analysis period (in years) during which project alternatives will be compared. Refer to Table 2 in Section 2.2, “Determining an Analysis Period,” to decide on the common analysis period appropriate to the pavement design lives being considered..
- *Discount Rate (%)*: Enter the Caltrans default value of 4 percent for deterministic analysis.
- *Beginning of Analysis Period*: Enter the year in which the project alternative is expected to be constructed. This should be the same year as the one used to calculate the initial or construction year AADT in the design designation (HDM Index 103.1). If the project did not require a design designation (i.e. traffic projections) or traffic projections were not done, use the year you expect the project will complete construction.
- *Include Agency Cost Remaining Service Life Value*: Click the checkbox to have *RealCost* include the RSL value of a project alternative [i.e., prorated share of total cost (including agency and user costs) of last rehabilitation activity] when computing life-cycle cost of the project alternative.

- *Include User Costs in Analysis*: Click the checkbox to have *RealCost* include user costs in the analysis and display the calculated user costs results.
- *User Cost Computation Method*: Select "Calculated" to have *RealCost* calculate user costs based on project-specific input data.

> ***Note:***
>
> *As an option, CA4PRS can be used to calculate the user costs for the life cycle cost analysis. CA4PRS (Construction Analysis for Pavement Rehabilitation Strategies) is a software developed by Caltrans and others to compare various traffic management alternatives for their impacts on construction schedules and the traveling public. One of the outputs from the program is user costs. The program is currently limited on what options it can investigate but is being expanded as resources allow. The latest version of CA4PRS and the user manual can be obtained from the Division of Research and Innovation Web site at:*
>
> *http://www.dot.ca.gov/research/roadway/ca4prs/ca4prs.htm*
>
> *If CA4PRS data is used, Ca4PRS runs will be needed for all of the initial construction options and future rehabilitation options. If CA4PRS generated data is used, select "Specified" under "User Cost Computation Method".*

- *Traffic Direction*: Directs *RealCost* to calculate user costs for the "Inbound" lanes, the "Outbound" lanes, or "Both" lanes. Select the traffic lanes, which will be affected by work zone operations. "Inbound" is used for the direction where traffic peaks in the AM hours. "Outbound" is used for the direction where traffic peaks in the PM hours. "Both" is used when construction is occurring in both directions.
- *Include User Cost Remaining Service Life Value (RSV)*: Click the checkbox to have *RealCost* include the (RSV) of a project alternative [i.e., prorated share of total cost (including agency and user costs) of last rehabilitation activity] when computing life-cycle cost of the project alternative.

Once all the analysis options are defined, click the "Ok" button to return to the "Switchboard" or the "Cancel" button to start again.

3.2.3 Traffic Data

The "Traffic Data Form" (Figure 7) is used to enter project-specific traffic data that will be used exclusively to calculate work zone user costs in accordance with the method outlined in the FHWA's *LCCA Technical Bulletin* (1998) and "Life-Cycle Cost Analysis in Pavement Design." Traffic data are developed for PIDs and PRs when pavement work is involved. Some of the data for "Traffic Data Form" will need to come from the design designations (traffic projections) generated for the specific project and from the Division of Traffic Operations web site (http://www.dot.ca.gov/hq/traffops/saferesr/trafdata/index.htm).

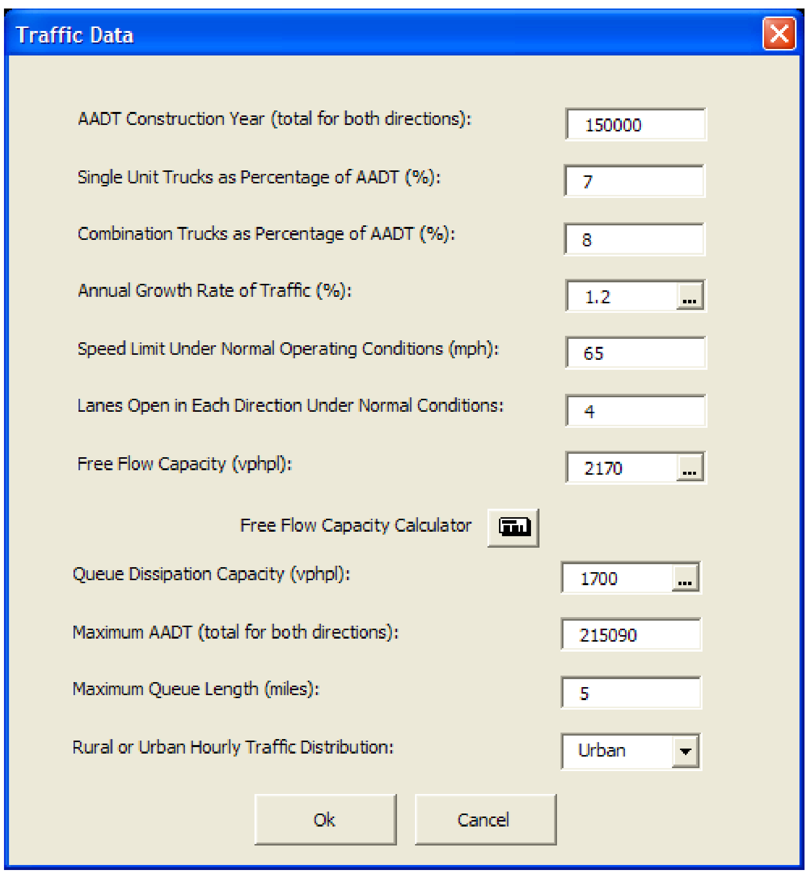


Figure 7. Traffic Data Form

3.2.3.1 AADT Construction Year (total for both directions): Enter the annual average daily traffic (AADT) total for both directions in the beginning year of the analysis. This is the same as the construction year AADT found in the design designation (traffic projections) for the project (see HDM Index 103.1). For an example of what to do if a design designation or traffic forecast was not developed for the project, see Appendix 7.

3.2.3.2 Single Unit Trucks as Percentage of AADT (%): Enter the percentage of the AADT that is single unit trucks (i.e., commercial trucks with two-axles and four tires or more) by doing the following:

1) Go to the Division of Traffic Operations web site (http://www.dot.ca.gov/hq/traffops/saferesr/trafdata/index.htm) and Find the most current year Truck AADT data available (such as "2005Truck" in excel file form). Find "2 Axle Percent (percentage of Truck AADT Total)" at the project location. There may be several values given within the limits of the project. Choose the one that best represents the overall project. A weighted average may also be used. Whatever value is selected is to be applied to all project alternatives investigated.

2) Obtain the truck traffic volume (T) from the design designation (HDM Topic 103.1). This value is measured as a percentage. If there is no design designation, use the Total Trucks % value from the Division of Traffic Operations web site referred to in step 1.

> ***Note:***
>
> *The total truck volume in the design designation does not need to match the total truck*

percentage on the Division of Traffic Operations website. If there is a wide disparity in values between the two numbers, the designer should review the accuracy of the traffic projections in the design designation and have the design designation updated if necessary.

3) Using Equation 2 to calculate the "Single Unit Trucks as Percentage of AADT (%)" (Assumption: "Total Trucks %" and "Single Unit Trucks %" will remain the same in future years):

$$SUT = T \times (\frac{TA}{100}) \qquad \text{(Equation 2)}$$

where

SUT = Single Unit Trucks as Percentage of AADT (%)

T = Total Truck Volume (%) or Total Trucks % (percentage of AADT Total).

TA = 2 Axle Percent (percentage of Truck AADT Total).

Example:

Given:

Total Trucks % = 6.22%

2 Axle Percent = 33.93%

Find: The Single Unit Trucks as Percentage of AADT

Using Equation 2, the Single Unit Trucks as Percentage of AADT (%) is

$$6.22 \times (\frac{33.93}{100}) = 2.11\% \rightarrow \textit{Round to 2.1\%}$$

3.2.3.3 Combination Trucks as Percentage of AADT (%): Enter the percentage of the AADT that is combination trucks (i.e., commercial trucks with three axles or more). This value is obtained by subtracting the "Single Unit Trucks as Percentage of AADT (%)" from the "Total Trucks % (percentage of AADT Total)."

3.2.3.4 Annual Growth Rate of Traffic (%): Enter the percentage by which the AADT in both directions will increase each year. Contact the Division of Traffic System Information for the "Annual Growth Rate of Traffic" or calculate the approximate value with the available AADT values (in the most current and future years) using the following equation:

$$A = \left(\frac{FT}{CT}\right)^{\left(\frac{1}{FY-CY}\right)} \qquad \text{(Equation 3)}$$

where:

A = Annual Growth Rate of Traffic

FT = Future Year AADT obtained from the project design designation (HDM 103.1)

CT = Construction Year AADT obtained from the project design designation (HDM 103.1)

FY = Future Year in which AADT is available

CY = Most Current Year in which AADT is available.

> ***Example:***
>
> *Given:*
>
> *Future Year AADT (total for both directions) = 18,000 (year 2025)*
>
> *Construction Year AADT (total for both directions) = 9,800 (year 2005)*
>
> *The Annual Growth Rate of Traffic is:*
>
> $$\left(\frac{18{,}000}{9{,}800}\right)^{\left(\frac{1}{2025-2005}\right)} = 1.03\%$$

3.2.3.5 Speed Limit under Normal Operating Conditions (mph): Enter the posted speed limit at the project location. If a roadway is being newly built, enter an anticipated speed limit based on traffic laws. District Traffic Operations can provide a recommendation if needed.

3.2.3.6 Lanes Open in Each Direction under Normal Conditions: Enter the number of lanes open to traffic in each direction during normal operating hours. For widening of existing roadway, enter the number of existing lanes, not the future number of lanes. If a roadway is being newly built, enter the designed number of lanes.

3.2.3.7 Free Flow Capacity (vphpl): Enter the number of vehicles per hour per lane (vphph) during normal operating hours. Table 6 provides typical values for standard lane and shoulder widths for various types of terrain. If there are nonstandard lane and shoulder widths or if it is desired to get a more specific free flow capacity, click the "Free Flow Capacity Calculator" in *RealCost* to open a form that calculates free flow capacities based upon the Highway Capacity Manual (1994), 3rd Ed. To use the calculator, the following project-specific information is needed: number of lanes in each direction, lane width, proportion of trucks and buses, upgrade, upgrade length, obstruction on two sides, and distance to obstruction/shoulder width.

Note:

Additional information on how to estimate "Free Flow Capacity" can be found in Appendix 5.

Table 6. Traffic Input Values

	Two-Lane Highways			**Multi-Lane Highways**		
Type of Terrain	Level	Rolling	Mountainous	Level	Rolling	Mountainous
Free Flow Capacity (vphpl)	1,620	1,480	1,260	2,170	1,950	1,620
Queue Dissipation Capacity (vphpl)	1,710	1,570	1,330	1,700	1,530	1,270
Maximum AADT Per Lane	40,955	37,390	31,850	53,773	48,305	40,140
Work Zone Capacity (vphpl)(1)	1,050	960	820	1,510	1,360	1,130
Maximum Queue Length	7.0 miles if the estimated maximum queue length is longer than 7.0 miles			5.0 miles if the estimated maximum queue length is longer than 5.0 miles		

Notes:
* Refer to the calculation procedures included in Appendix 4, "Traffic Inputs Estimation".
(1) Assumed one lane to be open for traffic in single-lane highways and two or more lanes to be open for traffic in multi-lane highways.

3.2.3.8 Queue Dissipation Capacity (vphpl): Enter the vehicles per hour per lane capacity of each lane during queue-dissipation operating conditions. Table 6 provides values for typical two-lane and multi-lane (in each direction) highways. As an alternative, the numbers may be estimated using the procedures for "Queue Dissipation Capacity" in Appendix 5.

3.2.3.9 Maximum AADT (total for both directions): Enter the maximum AADT (total for both directions) at which the traffic growth will be capped. This value recognizes that there is only so much traffic that can be placed on a roadway. If traffic grows beyond this value, it will be substituted for the computed future AADT value and future user costs will be calculated based upon it. Table 6 provides recommended per lane values for typical two-lane and multi-lane highways. As an alternative, the numbers may be estimated using the procedures for "Maximum AADT" in Appendix 5.

3.2.3.10 Maximum Queue Length (miles): Enter a practical maximum length of queue in miles. Reasonable maximum queue length could be one or two exits prior to the work zone or an exit that leads to a reasonable alternate route. Queue-related user costs, which are based upon queue length, will be calculated with this value in cases when the *RealCost*-calculated queue lengths exceed this value. **If a project-specific value is not available, enter seven (7) miles for two-lane highways and five (5) miles for multi-lane highways respectively.**

Note:

Appendix 5 provides an explanation on the demand-capacity model – queuing theory – that RealCost uses in calculating maximum queue length.

3.2.3.11 Rural or Urban Hourly Traffic Distribution: Select “Rural” or “Urban” depending on the project location. For details on Caltrans roadway classifications, visit the Division of Traffic System Information website at http://www.dot.ca.gov/hq/tsip/hpms/Page1.php.

Once all the traffic data has been entered, click the “Ok” button to return to the Switchboard or the “Cancel” button to start over.

3.2.4 Value of User Time

The “Value of User Time Form” (Figure 8) is used to enter the values applied to an hour of user time. The dollar value of user time is typically different for each type of vehicle and is used to calculate user costs associated with delay during work zone operations. Enter the following values:

- $10.46 per hour for passenger cars.
- $27.83 per hour for single unit trucks.
- $27.83 per hour for combination trucks.

These dollar values are based upon the Caltrans’ Cal-B/C model (2004). Once the dollar values have been entered, click the “Ok” button to return to the “Switchboard” or click the “Cancel” button to start over.

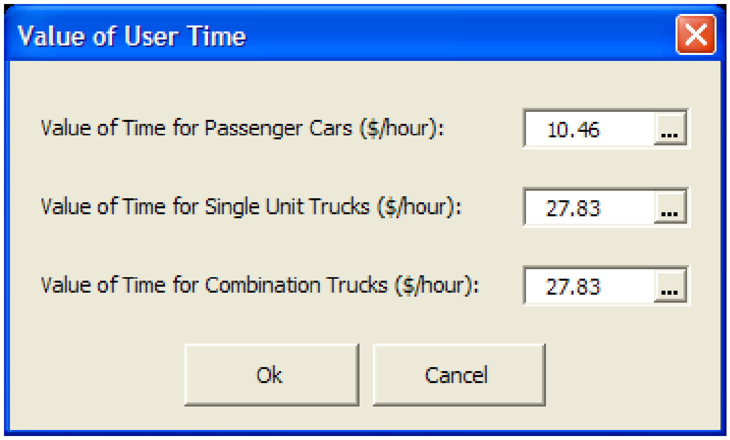


Figure 8. Value of User Time Form

3.2.5 Traffic Hourly Distribution

The "Traffic Hourly Distribution" Form (Figure 9) allows adjustment to (or restoration of) the default values for rural and urban traffic, which are used in converting AADT to an hourly traffic distribution. If project-specific data is not available, use the California weekday default values (Figure 9). (Click the "Traffic Hourly Distribution" button on the *RealCost* Switchboard (Figure 4) to see the default values.) These values were generated from Caltrans traffic count data (April 2005 data by the Division of Traffic Operations) at selected highway locations.

Traffic Hourly Distribution

Hour	AADT Rural (%)	Inbound Rural (%)	Outbound Rural (%)	AADT Urban (%)	Inbound Urban (%)	Outbound Urban (%)
0 - 1	1.62	48.8	51.2	0.92	48	52
1 - 2	1.3	52.1	47.9	0.62	49.5	50.5
2 - 3	1.3	53.5	46.5	0.58	51.9	48.1
3 - 4	1.52	59.3	40.7	0.78	56.8	43.2
4 - 5	2.14	62.1	37.9	1.59	61.3	38.7
5 - 6	3.43	59.8	40.2	3.11	60.3	39.7
6 - 7	4.79	58.5	41.5	5.01	58.4	41.6
7 - 8	5.3	57.8	42.2	6.04	57.6	42.4
8 - 9	5.12	56	44	5.8	55.9	44.1
9 - 10	5.1	54.3	45.7	5.46	53.9	46.1
10 - 11	5.24	52.5	47.5	5.44	51.4	48.6
11 - 12	5.43	51.2	48.8	5.78	50.1	49.9
12 - 13	5.63	50.9	49.1	6.03	49.1	50.9
13 - 14	5.74	51.2	48.8	6.11	48.4	51.6
14 - 15	6.11	50.3	49.7	6.52	46.3	53.7
15 - 16	6.57	48.8	51.2	7.03	44.6	55.4
16 - 17	6.73	47.5	52.5	7	43.4	56.6
17 - 18	6.4	45.2	54.8	6.54	43.4	56.6
18 - 19	5.32	45.6	54.4	5.35	44.4	55.6
19 - 20	4.31	44.6	55.4	4.22	44.8	55.2
20 - 21	3.57	45.6	54.4	3.54	45.4	54.6
21 - 22	3.03	46	54	2.95	45.9	54.1
22 - 23	2.4	47.1	52.9	2.18	47.2	52.8
23 - 24	1.9	47.1	52.9	1.4	45.1	54.9
Total	100			100		

Restore Defaults Ok

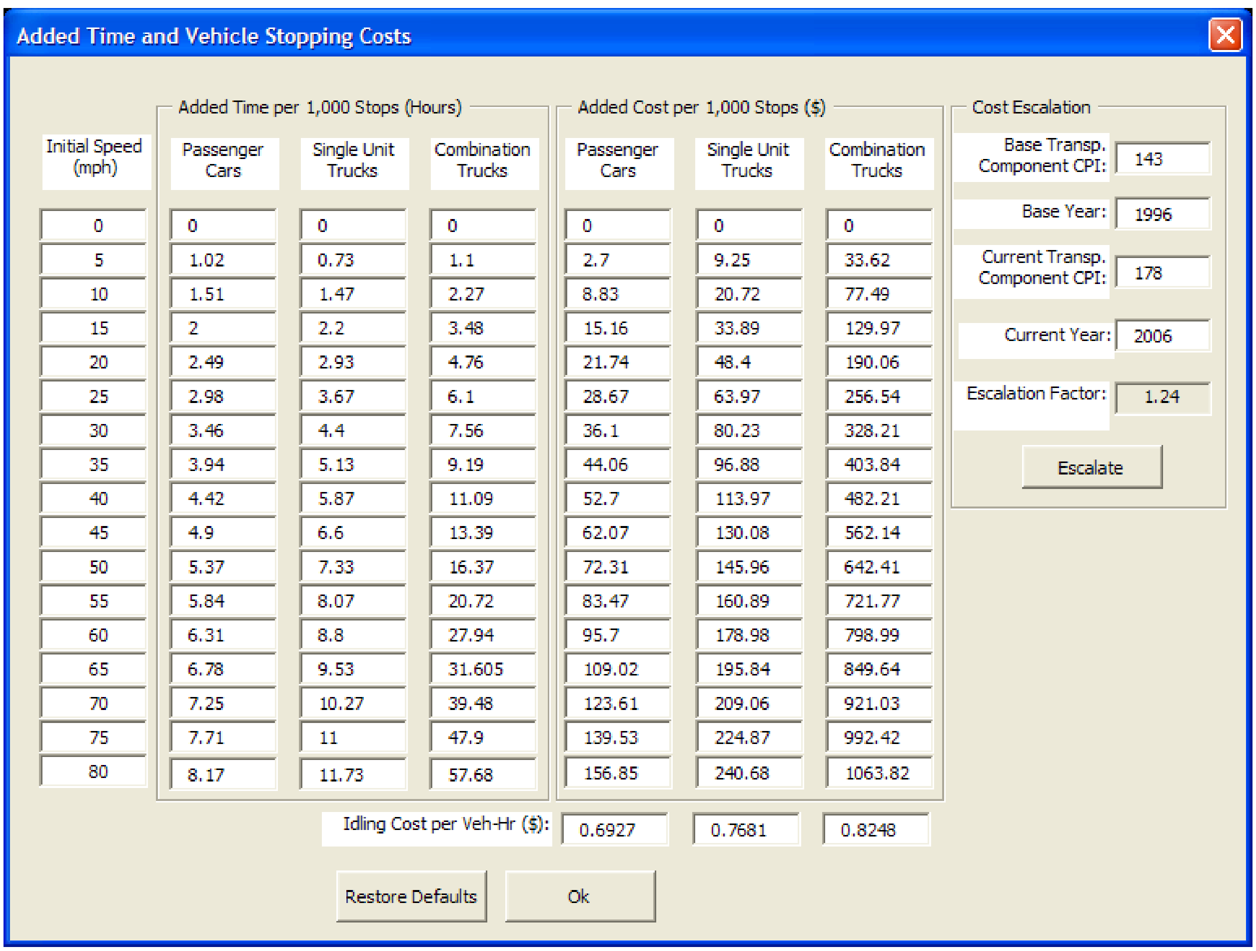
Figure 9. Traffic Hourly Distribution Form with California Weekday Default Values

Note:

Currently the program only contains data for weekday "Traffic Hourly Distribution" which will not fit alternatives that use weekend closures. Efforts are currently underway to add a weekend "Traffic Hourly Distribution" to the program. Until the weekend data is included, alternatives that use weekend closures will need to be run separately from the other alternatives and weekend "Traffic Hourly Distribution" data will need to be entered manually. California default weekend "Traffic Hourly Distribution" data can be found in Appendix 7.

3.2.6 Added Time and Vehicle Stopping Costs

The “Added Time and Vehicle Stopping Costs Form” (Figure 10) is used to adjust the default values for added time and added cost per 1,000 stops. The default values are based upon the National Cooperative Highway Research Program (NCHRP) Study 133 (1996), *Procedures for Estimating Highway User Costs, Air Pollution, and Noise Effects.* These values are used to calculate user delay and vehicle costs due to speed changes that occur during work zone operations. The “Idling Cost per Veh-Hr ($)” is used to calculate the additional vehicle operating costs that result from a traffic queue under stop-and-go conditions.



Added Time and Vehicle Stopping Costs

	Added Time per 1,000 Stops (Hours)			Added Cost per 1,000 Stops ($)		
Initial Speed (mph)	Passenger Cars	Single Unit Trucks	Combination Trucks	Passenger Cars	Single Unit Trucks	Combination Trucks
0	0	0	0	0	0	0
5	1.02	0.73	1.1	2.7	9.25	33.62
10	1.51	1.47	2.27	8.83	20.72	77.49
15	2	2.2	3.48	15.16	33.89	129.97
20	2.49	2.93	4.76	21.74	48.4	190.06
25	2.98	3.67	6.1	28.67	63.97	256.54
30	3.46	4.4	7.56	36.1	80.23	328.21
35	3.94	5.13	9.19	44.06	96.88	403.84
40	4.42	5.87	11.09	52.7	113.97	482.21
45	4.9	6.6	13.39	62.07	130.08	562.14
50	5.37	7.33	16.37	72.31	145.96	642.41
55	5.84	8.07	20.72	83.47	160.89	721.77
60	6.31	8.8	27.94	95.7	178.98	798.99
65	6.78	9.53	31.605	109.02	195.84	849.64
70	7.25	10.27	39.48	123.61	209.06	921.03
75	7.71	11	47.9	139.53	224.87	992.42
80	8.17	11.73	57.68	156.85	240.68	1063.82
Idling Cost per Veh-Hr ($):				0.6927	0.7681	0.8248

Cost Escalation

Base Transp. Component CPI:	143
Base Year:	1996
Current Transp. Component CPI:	178
Current Year:	2006
Escalation Factor:	1.24

Escalate

Restore Defaults Ok

Figure 10. Added Time and Vehicle Stopping Costs Form

The default values, expressed in 1996 dollars, are adjusted to the current year dollar amounts by entering the transportation-component Consumer Price Index (CPI) of the base (1996) and current years. Table 7 shows the transportation-component CPI's collected and projected by the California Department of Finance. Since the statewide transportation-component CPI's are not available yet, the U.S. transportation-component CPI's (in bold text) can be used.

Example:

1. *For a 2006 year analysis:Enter "1996" for "Base Year" and "143.0" for "Base Transp. Component CPI"*
2. *Enter "2006" for "Current Year" and "178.0" for "Current Transp. Component CPI"*
3. *Click the "Escalate" button (see Figure 10).*

The program will update the cost data. To get back to the default values, click the "Restore Defaults" button.

Table 7. Transportation Component Consumer Price Indexes

Year	US	LA CMSA(1)	SF CMSA(2)
1996	**143.0**	144.3	133.5
1997	**144.3**	145.2	133.6
1998	**141.6**	142.6	132.0
1999	**144.4**	146.8	135.8
2000	**153.3**	154.2	143.1
2001	**154.3**	155.3	143.7
2002	**152.9**	154.5	141.0
2003	**157.6**	160.3	145.0
2004	**163.1**	166.5	149.6
2005	**175.2**	176.2	157.3
2006	**178.0**	177.1	159.3
2007	**177.2**	171.6	156.2
2008 & beyond	**177.9**	167.3	154.1

Notes:
* Source: California Department of Finance, Economic Research Unit
http://www.dof.ca.gov/HTML/FS_DATA/LatestEconData/FS_Price.htm
(1) LA CMSA (Consolidated Metropolitan Statistical Area): includes counties of Los Angeles, Orange, Riverside, San Bernadino, & Ventura
(2) SF CMSA (Consolidated Metropolitan Statistical Area): includes counties of Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Santa Cruz, Solano, & Sonoma

3.2.7 Save Project-Level Inputs

To save the project file, go back to the *RealCost* Switchboard (Figure 4) and click the "Save Project-Level Inputs" button. The user can save the project-level inputs at a preferred location under a user-specified name, and the file will be automatically saved with the *.LCC extension. To retrieve the file later, click the "Open Project Level Inputs" button located on the Switchboard.

Note:

Saving the project-level inputs does not make any changes made to default data in "Traffic Hourly Distribution" or "Added Time and Vehicle Stopping Costs." Any of this project-specific data must be reentered when reopening RealCost.

3.3 Alternative-Level Inputs

The "Alternative 1" (Figure 11) and "Alternative 2" Forms are identical and are used to input information for the project alternatives being analyzed (i.e., the agency costs and work zone specifics for initial construction and future rehabilitation activities of each alternative). Each project alternative can include up to six future rehabilitation activities ("Rehabilitation 1" through "Rehabilitation 6") after the initial construction (i.e., project alternative). The data describing these activities must be entered sequentially according to the pavement M&R

schedule selected for each project alternative. For example, "Initial Construction" precedes "Rehabilitation 1" and "Rehabilitation 3" precedes "Rehabilitation 4."

Note:

Because many projects will need at least 3 alternatives analyzed to meet the alternative requirements in Section 2.1 and the program currently can only analyze two alternatives at a time, multiple runs of the program will be needed to cover all the needed alternatives. Caltrans is currently working with FHWA to expand the number of alternatives that can be analyzed at once in the program.

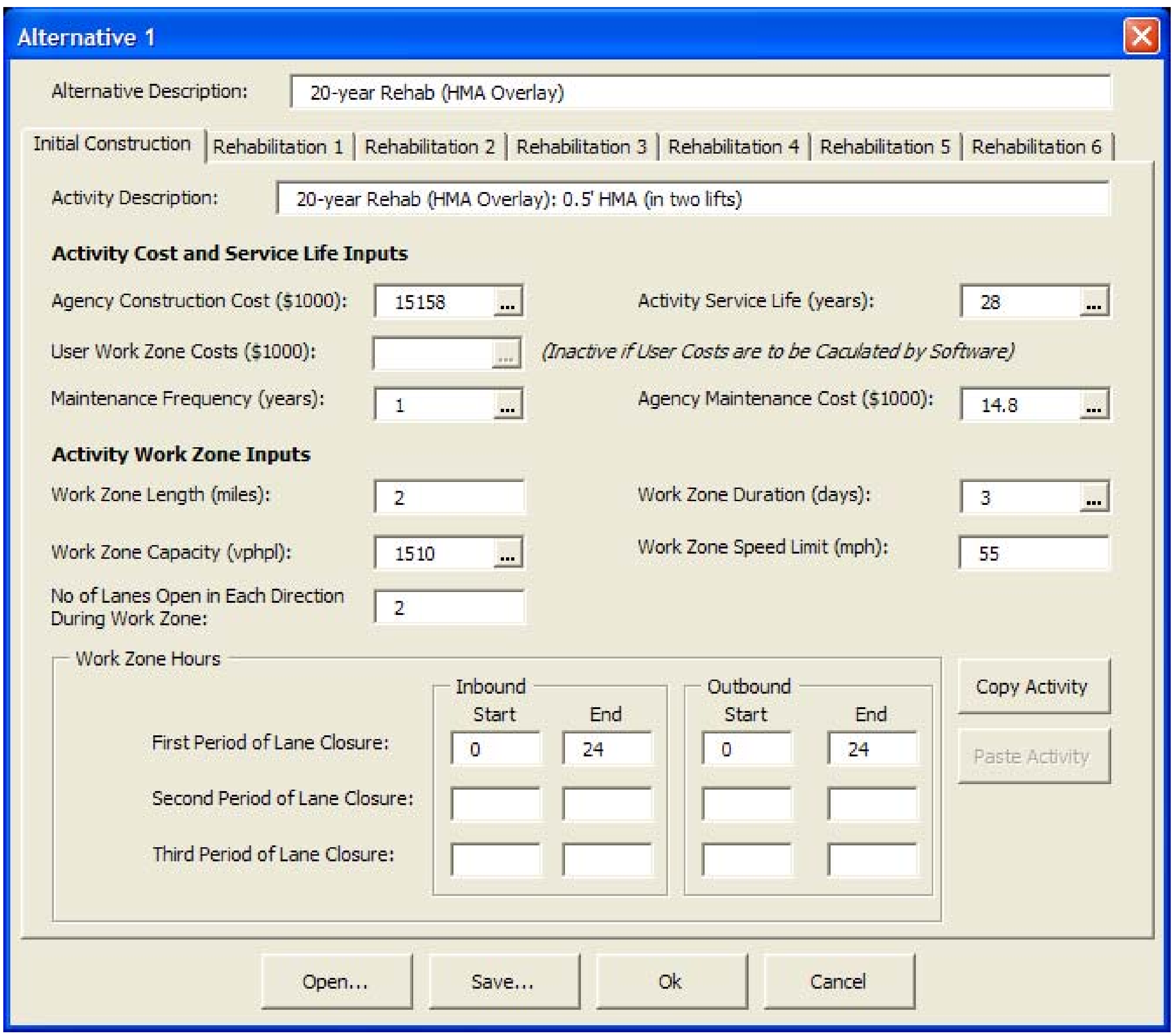


Figure 11. Alternative 1 Form (Same as Alternative 2 Form)

The data inputs required under each activity tab on the form are described below.

- *Alternative Description*: Enter a description for the project alternative such as "20-year Rehab (HMA Overlay)."
- *Activity Description*: Enter a description for the initial construction or future rehabilitation activities being considered for each project alternative.
- *Agency Construction Cost ($1000)*: Under the "Initial Construction" tab, enter the total initial cost in thousands of dollars (engineer's estimate plus project support costs) for a project alternative (see Section 2.5.1, "Initial Costs"). For future rehabilitation activities to be implemented after the initial construction (i.e., project alternative), enter the total rehabilitation costs in thousands of dollars under the "Rehabilitation" tabs for each future rehabilitation activity (see Section 2.5.3, "Rehabilitation Costs").
- *Activity Service Life (years)*: Enter the activity service life of initial construction (under "Initial Construction" tab) or that of future rehabilitation activity to be followed (under each "Rehabilitation" tab). Refer to Appendix 4 for a pavement M&R schedule applicable for each project alternative and activity service lives estimated for initial construction and future rehabilitation activities scheduled to be implemented for each project alternative (see the example in Section 2.5.3, "Rehabilitation Costs").
- *User Work Zone Costs ($1000)*: This field should be inaccessible since the "User Cost Computation Method" on the "Analysis Options Form" (Figure 6) is set to "Calculated" as the default. If this is not the case, go to "Analysis Options Form" to modify the "User Cost Computation Method."
- *Maintenance Frequency (years)*: This refers to the cyclical frequency of interim preventive, corrective, and routine maintenance treatments to follow after the initial construction or after each future rehabilitation activity. Enter one (1) year as the "Maintenance Frequency," since the annualized maintenance cost will be entered as "Agency Maintenance Cost," as described below (see the example in Section 2.5.3, "Rehabilitation Costs").

- *Agency Maintenance Cost ($1000)*: As discussed in Section 2.5.2, "Maintenance Costs," this includes the costs of preventive, corrective, and routine maintenance treatments to preserve or to extend the service life of initial construction and any future rehabilitation activities. See the example in Section 2.5.3, "Rehabilitation Costs" for details on how to calculate this cost.

- *Work Zone Length (miles)*: This refers to the length in miles of the work zone being considered for initial construction or for each future rehabilitation activity. The work zone length should be based on what is allowed from the Traffic Management Plan (TMP) for the initial construction or historical experience. It should be measured from beginning to end of the reduced speed area where the work zone speed limit will be in effect. Information and recommendations can be obtained from the District Construction and Traffic Operations if needed.

- *Work Zone Duration (days)*: This refers to the number of days during which the work zone will be affecting traffic. For example, if the work zone is in effect five days a week for four weeks, the duration is twenty. If the work zone is in effect over the weekend (2-½ day closure) for ten weekends, the duration is ten because the duration lasts for more than one day before the lane is reopened.

Note:

Several special cases to be aware of:

Continuous lane closures – If a lane is closed for the duration of the contract, it is treated as a 24 hour closure (from hour 0 to hour 24) for each working day it is closed. Therefore, if the lane is closed for 3 months, the total number of closures is 3 months x 21 work days per month or 63 days.

Weekend (55-hour) closures – multiply 2.3 (=55/24) to the number of closures needed in order to get the number of days needed. This is necessary because the RealCost program can only analyze closures within a 24-hour period and weekend closures last for over 2days.

Work not requiring a lane closure – In some instances, lanes can be detoured and work can be done behind K-rail or other separation from traffic. In this instance, if lanes do not *need to be closed to do paving for the work done behind the K-rail so the work zone duration for this work is zero.*

The estimated work zone duration for initial construction should be estimated as part of the project estimate cost. **It is not the same as the number of working days used to build the project. It is the estimated number of times the lane(s) will need to be closed to do the necessary work to the pavement.**

Shown in Tables 8 and 9 are the estimates of work that can be completed with different construction windows (such as nighttime closure, weekend closure, etc.) for typical M&R strategies for flexible pavements (Table 8) and for rigid and composite pavements (Table 9). These production rates are estimated with *CA4PRS* (Construction Analysis for Pavement Rehabilitation Strategies) software assuming typical working conditions and resource configurations observed in the past projects.

Note:

The latest version of CA4PRS and the user manual can be obtained from the Division of Research and Innovation Web site at:

http://www.dot.ca.gov/research/roadway/ca4prs/ca4prs.htm.

Because user costs can have a major impact on the results, it is important to be using the most cost effective traffic management practice possible. In some cases, such as when comparing flexible and rigid pavement strategies, the most cost effective traffic management plan may not be the same for all the alternatives (initial and future rehabilitation) being considered. If the traffic management plan does not provide a strategy for the initial or future rehabilitation strategy or if the strategy needs to be checked to be sure it is the most cost effective, the designer can use the construction traffic analysis software CA4PRS (freeways only) to analyze options or can do the following quick check:

1) Use Equation 5 to calculate the number of closures needed to maximize work zone length with each construction window.

$$CN_{\max} = \frac{MWZ \times 2}{PR} \qquad \text{(Equation 5)}$$

where

CN_{max} = No. of Closures needed for the Maximum Work Zone Length

MWZ = Maximum Work Zone Length

PR = Production Rate (lane-mile/closure)

2) Identify those construction windows whose $CN_{\max}$ is larger than 1 (*Note*: if CN_{max} of a particular construction window is less than 1, that traffic management strategy should not be evaluated further.)

3) Use Equation 6 to calculate the total closure time needed for the maximum work zone length,

$$CT_{\max} = CN_{\max} \times CH \qquad \text{(Equation 6)}$$

where

CT_{max} = Total Closure Time Needed for the Maximum Work Zone Length

CN_{max} = No. of Closures Needed for the Maximum Work Zone Length

CH = Closure Hours

4) Identify the construction window with the lowest $CT_{max.}$ If this strategy is a plausible traffic management strategy, it can be used in lieu of the one in the traffic management plan for future rehabilitation activities. Note that if the analysis is done and used for one alternative or future rehabilitation strategy, it must be used for all alternatives and future rehabilitation strategies. This is necessary to assure that the answers from the analysis are consistent and comparable to each other.

- *Work Zone Capacity (vphpl)*: Enter the vehicular capacity of one lane of the work zone for one hour. Table 6 provides values for typical single-lane and multi-lane (in each direction) highways. As an alternative, the numbers may be estimated using the procedures for “Work Zone Capacity” in Appendix 5.

- *Work Zone Speed Limit (mph)*: This is the expected operating speed within the work zone. Enter a speed that is 5 mph less than the posted speed limit unless there is an approved reduced speed limit for the project. Approved reductions in posted speed limits can be found in the traffic management plan.

- *No of Lanes Open in Each Direction During Work Zone*: Enter the number of lanes to be open when the work zone is in effect. The number of lanes to be open applies to each direction. This information can be obtained from the traffic management plan or District Traffic Operations.

- *Work Zone Hours*: Enter the zone hours from 0 to 24 using a 24-hour clock during which the work zone is in effect. Work zone timing can be modeled separately for inbound and outbound traffic for up to three separate periods for each day. During these hours, road capacity is limited to the work zone capacity. Work zone hours can be obtained from the traffic management plan or District Traffic Operations. If the traffic management plan includes variable work zone hours (lane closures) for the project, use the hours that apply most often to the project as a whole.

Table 8. Productivity Estimates of Typical Future Rehabilitation Strategies for Flexible Pavements

Final Surface Type	Future M&R Alternative	Pvmt Design Life (years)	Maint. Service Level	Description	Average Lane-mile Completed Per Closure(1)				
					Daily Closure (Weekday)		Continuous Closure		Weekend Closure(4) (55-Hour)
					5 to 7-Hour Closure	8 to 12-Hour Closure	16 hour/day Operation(2)	24 hour/day Operation(3)	
CAPM									
HMA	HMA Overlay	5+	1,2,3	0.20' HMA	0.79	1.87	3.21	5.35	19.62
	Mill & Overlay with HMA	5+	1,2,3	0.20' Mill plus 0.20' HMA	UD	0.68	1.25	2.16	6.51
HMA w/ OGFC	HMA w/ OGFC Overlay	5+	1,2,3	0.10' OGFC over 0.20' HMA	0.28	1.08	1.90	3.17	18.73
	Mill & Overlay with HMA w/ OGFC	5+	1,2,3	0.20' Mill plus 0.10' OGFC over 0.20' HMA	UD	0.40	0.84	1.45	4.51
HMA w/ RAC	HMA w/ RAC Overlay	5+	1,2,3	0.10' RAC over 0.20' HMA	0.28	1.08	1.90	3.17	11.64
	Mill & Overlay with HMA w/ RAC	5+	1,2,3	0.20' Mill plus 0.10' RAC over 0.20' HMA	UD	0.40	0.84	1.45	4.51
RAC-G	RAC-G Overlay	5+	1,2,3	0.15' RAC-G	1.18	2.79	4.80	8.00	29.28
	Mill & Overlay with RAC-G	5+	1,2,3	0.15' Mill plus 0.15' RAC-G	0.27	0.86	1.58	2.70	8.10
RAC-G w/ RAC-O	RAC-G w/ RAC-O Overlay	5+	1,2,3	0.10' RAC-O over 0.15' RAC-G	0.55	1.35	1.41	3.95	14.48
	Mill & Overlay with RAC-G w/ RAC-O Overlay	5+	1,2,3	0.15' Mill plus 0.10' RAC-O over 0.15' RAC-G	UD	UD	UD	UD	UD
Roadway Rehabilitation									
HMA	HMA Overlay	10	1,2,3	0.35' HMA (in two lifts)	UD	0.66	1.35	2.27	8.36
		20	1,2,3	0.50' HMA (in two lifts)	UD	0.33	0.75	1.60	5.87
	Mill & Overlay with HMA	10	1,2,3	0.35' Mill plus 0.35' HMA (in two lifts)	UD	UD	0.53	1.05	3.36
		20	1,2,3	0.50' Mill plus 0.50' HMA (in two lifts)	UD	UD	0.30	0.73	2.27
HMA w/ OGFC	HMA w/ OGFC Overlay	10	1,2,3	0.10' OGFC over 0.35' HMA (in two lifts)	UD	0.52	0.80	1.75	5.82
		20	1,2,3	0.10' OGFC over 0.50' HMA (in two lifts)	UD	UD	0.52	1.30	4.87
	Mill & Overlay with HMA w/ OGFC	10	1,2,3	0.35' Mill plus 0.10' OGFC over 0.35' HMA (in two lifts)	UD	UD	0.28	0.71	2.55
		20	1,2,3	0.50' Mill plus 0.10' OGFC over 0.50' HMA (in two lifts)	UD	UD	UD	0.81	1.76
HMA w/ RAC	HMA w/ RAC Overlay	10	1,2,3	0.10' RAC over 0.35' HMA (in two lifts)	UD	0.52	0.80	1.75	5.82
		20	1,2,3	0.10' RAC over 0.50' HMA (in two lifts)	UD	UD	0.52	1.30	4.87
	Mill & Overlay with HMA w/ RAC	10	1,2,3	0.35' Mill plus 0.10' RAC over 0.35' HMA (in two lifts)	UD	UD	0.28	0.71	2.55
		20	1,2,3	0.50' Mill plus 0.10' RAC over 0.50' HMA (in two lifts)	UD	UD	UD	0.50	1.76
RAC-G	RAC-G Overlay	10	1,2,3	0.20' RAC-G	0.79	1.87	3.21	5.35	19.62
		20	1,2,3	0.20' RAC-G over 0.10' HMA	0.48	1.12	1.93	3.22	11.82
	Mill & Overlay with RAC-G	10	1,2,3	0.20' Mill plus 0.20' RAC-G	UD	0.68	1.25	2.16	6.51
		20	1,2,3	0.30' Mill plus 0.20' RAC-G over 0.10' HMA	UD	0.40	0.85	1.47	4.54
RAC-G w/ RAC-O	RAC-G w/ RAC-O Overlay	10	1,2,3	0.10' RAC-O over 0.20' RAC-G	0.28	1.08	1.90	3.17	11.64
		20	1,2,3	0.10' RAC-O over 0.20' RAC-G over 0.10' HMA	UD	0.66	1.35	2.27	8.36
	Mill & Overlay with RAC-G w/ RAC-O	10	1,2,3	0.20' Mill plus 0.10' RAC-O over 0.20' RAC-G	UD	0.4	0.84	1.45	4.54
		20	1,2,3	0.30' Mill plus 0.10' RAC-O over 0.20' RAC-G over 0.10' HMA	UD	UD	0.53	1.05	3.36

Notes:
UD - Under Development. See Office of Pavement Design for Assistance
* Refer to Appendix 1, "Glossary and List of Acronyms" for definitions of terms used in the table.
* Refer to Appendix 3 for a expanded version of the table.
(1) Production rates in this table are based on representative assumptions that are applied consistantly throughout the table. These rates are only for calculating calculating future user costs using the procedures in this manual and not for any other purpose. More project specific user costs for some freeway situations can be obtained from the CA4PRS software.
(2) 24-hour continuous closure with 16 hours of operation per day
(3) 24-hour continuous closure with 24 hours of operation per day
(4) 55-hour extended closure over the weekend

Table 9. Productivity Estimates of Typical Future Rehabilitation for Rigid and Composite Pavements

Final Surface Type	Future M&R Alternative	Pvmt. Design Life (years)	Maint. Service Level	Description	Average Lane-mile Completed Per Closure[1]				
					Daily Closure (Weekday)		Continuous Closure		Weekend Closure[4] (55-Hour)
					5 to 7-Hour Closure	10-Hour Closure	16 hour/day Operation[2]	24 hour/day Operation[3]	
CAPM									
Flexible / Composite	Flexible Overlay	5+	1,2,3	0.15' Flexible	0.79	1.87	3.21	5.35	19.62
	Flexible Overlay w/ Slab Replacements	5+	1,2,3	2% Slab Replacements w/ 4-hr RSC (0.67') plus 0.15' Flexible Overlay	0.31	1.48	2.67		
		5+	1,2,3	2% Slab Replacements w/ 12-hr RSC (0.67') plus 0.15' Flexible Overlay			1.41	3.91	15.87
Rigid - Jointed Plain Concrete Pavement (JPCP)	Conc. Pvmt Rehab A[1]	5+	1,2,3	7% Slab Replacements w/ 4-hr RSC (0.67') plus Pavement Grinding	0.14	2.00	4.57		
		5+	1,2,3	7% Slab Replacements w/ 12-hr RSC (0.67') plus Pavement Grinding			0.71	4.14	23.71
	Conc. Pvmt Rehab B[2]	5+	1,2,3	5% Slab Replacements w/ 4-hr (0.67') plus Pavement Grinding	0.20	2.80	6.40		
		5+	1,2,3	5% Slab Replacements 12-hr RSC (0.67') plus Pavement Grinding			1.00	5.80	33.20
	Conc. Pvmt Rehab C[3]	10+/-	1,2,3	2% Slab Replacements w/ 4-hr (0.67') plus Pavement Grinding	0.50	7.00	16.00		
		10+/-	1,2,3	2% Slab Replacements w/ 12-hr RSC (0.67') plus Pavement Grinding			2.50	14.50	UD
Rigid - Continuously Reinforced Concrete Pavement	Punchout Repairs	TBD	1,2,3	Punchout Repairs w/ 4-hr RSC (0.83')	Under Development Contact Office of Pavement Design for Assistance				
		TBD	1,2,3	Punchout Repairs w/ 12-hr RSC (0.83')					
Roadway Rehabilitation									
Flexible / Composite	Flexible Overlay w/ Slab Replacements	10	1,2,3	5% Slab Replacements w/ 4-hr RSC (0.67') plus 0.25' Flexible Overlay	0.11	0.80	1.48		
		10	1,2,3	5% Slab Replacements w/ 12-hr RSC (0.67') plus 0.25' Flexible Overlay	UD	UD	0.66	2.07	8.72
	Crack, Seat, & Flexible Overlay	10	1,2,3	0.10' Flexible over Pvmt Reinforcing Fabric over 0.25' Flexible	UD	0.66	1.35	2.27	8.36
		20	1,2,3	0.10' Flexible over Pvmt Reinforcing Fabric plus 0.35' Flexible (in two lifts)	UD	0.52	0.80	1.75	5.82
	Replace with Flexible	20	1,2,3	0.10' Flexible over 0.64' Flexible (in three lifts)	UD	UD	0.74	1.70	6.31
		40	1,2,3	0.10' Flexible over 0.95' Flexible (in four lifts)	UD	UD	UD	1.22	3.06
	Replace with Composite	20	1,2,3	0.10' RAC-O over 0.75' 4-hr RSC over 0.50' Treated Base	Under Development Contact Office of Pavement Design for Assistance				
		20	1,2,3	0.10' RAC-O over 0.75' 12-hr RSC over 0.50' Treated Base					
		40	1,2,3	0.10' RAC-O over 0.83' 4 -hr RSC over 0.50' Treated Base					
		40	1,2,3	0.10' RAC-O over 0.83' 12-hr RSC over 0.50' Treated Base					
Rigid - Jointed Plain Concrete Pavement (JPCP)	Lane Replacement	20	1,2,3	0.83' 4-hr RSC over 0.50' Treated Base	0.01	0.06	0.13	0.23	0.82
		20	1,2,3	0.83' 12-hr RSC over 0.50' Treated Base			0.74	1.70	0.67
		40	1,2,3	1.00' 4-hr RSC over 0.50' Treated Base	0.01	0.06	0.12	0.21	0.75
		40	1,2,3	1.00' 12-hr RSC over 0.50' Treated Base			0.02	0.11	0.61
Rigid - Continuously Reinforced Concrete Pavement (CRCP)	Lane Replacement	20	1,2,3	0.75' 4-hr RSC over 0.50' Treated Base	Under Development Contact Office of Pavement Design for Assistance				
		20	1,2,3	0.75' 12-hr RSC over 0.50' Treated Base					
		40	1,2,3	0.83' 4 -hr RSC over 0.50' Treated Base					
		40	1,2,3	0.83' 12-hr RSC over 0.50' Treated Base					

Notes:
UD - Under Development. See Office of Pavement Design for Assistance
* Refer to Appendix 1, "Glossary and List of Acronyms" for definitions of terms used in the table.
* Refer to Appendix 3 for a expanded version of the table.
(1) Production rates in this table are based on representative assumptions that are applied consistantly throughout the table. These rates are only for calculating calculating future user costs using the procedures in this manual and not for any other purpose. More project specific user costs for some freeway situations can be obtained from the CA4PRS software.
(2) 24-hour continuous closure with 16 hours of operation per day
(3) 24-hour continuous closure with 24 hours of operation per day
(4) 55-hour extended closure over the weekend

Note:

For weekend closures, enter 0 to 24 on first line.

Example:

Determine the "Activity Work Zone Inputs" for future rehabilitation activities of the following project alternative:

5-year CAPM (0.20' HMA Overlay)

- *20.4 lane-miles (project length 3.4 miles, 3 lanes in each direction, mainline only) of existing flexible pavement*
- *Work Zone Duration (days): 12 days based upon the following information from the traffic management plan or assumed:*
  - *(a) Typical lane closure from 8 pm till 6 am the next morning.*
  - *(b) Single-lane paving with two lanes closed at one time.*
  - *(c) Approximately 1.7 lane-mile will be overlaid during each closure*
  - *(d) Work Zone Length of 1.4 miles at each closure*
- *Initial Construction Year: same as the beginning year of the analysis period*
- *Analysis Period: 20 years.*
- *Climate Region: South Coast*

Solution

1) Find an applicable pavement M&R schedule for the project alternative being considered. [from Appendix 4, Table F1-1 (2)]

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year		0		5		10	15		20		25	30
CapM (Pavement Rehabilitation)																
HMA	5	1,2		Year of Action		0		5			15		20			
				Activity Description		CapM (5 yr)		Rehab (10 yr)			CapM (5 yr)		Rehab (10 yr)			
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	5	1,096	10	2,675		5	1,096	10	2,675		

2) *Identify the future rehabilitation activities (including CAPM and reconstruction) whose year of action falls before the end of analysis period (20-year for this example.)*

   (a) *10-year Rehab in year 5*

   (b) *5-year CAPM in year 15*

   (c) *10-year Rehab in year 20*

3) *Find an applicable M&R alternative for each future rehabilitation activity ("Future M&R Alternative" in Table 8 or 9). Applicable M&R alternative for each future rehabilitation activity (from Table 8):*

   (a) *10-year Rehab in year 5: Mill and Overlay with HMA*

   (b) *5-year CAPM in year 15: HMA Overlay (Note: assumed cost to be the same as for initial construction)*

   (c) *10-year Rehab in year 20: Mill and Overlay with HMA*

4) *Find an applicable production rate estimate for each future rehabilitation activity (from Table 8 or 9) based on: project type of the future rehabilitation activity (i.e., CAPM or rehabilitation); final surface type of future rehabilitation activity; Applicable M&R alternative; pavement design life of the future rehabilitation activity (i.e., 5 years, 10 years, etc.).*

   (a) *10-year Rehab in year 5*

   - *Daily Closure (8-12 hours): 0.40 lane-mile/closure*

   (b) *5-year CAPM in year 15: all the work zone inputs are assumed to be same as for initial construction.*

   (c) *10-year Rehab in year 20: same as 4a) above*

5) *From the traffic management plan, a nighttime closure from 8 pm to 6 am the next day would equate to a daily closures of 8 to 12 hours.*

6) *Divide the total number of lane-miles of the paving by the production rate of the preferred construction window to get the "Work Zone Duration" (in terms of number of closures needed).*

(a) *10-year Rehab in year 5*

- *20.4 lane-miles ÷ 0.40 lane-miles/closure = 51 closures.*

(b) *5-year CAPM in year 15:*

- *12 days (Note: assumed to be same as the initial construction)*

(c) *10-year Rehab in year 20:*

- *Same as the above 10-year Rehab in year 5.*

Inputs to RealCost

1) *5-year CAPM in year 0: [to be entered under "Initial Construction" tab of "Alternative 1 Form" of RealCost (Figure 11)]*

   (a) *Work Zone Length (miles): 1.4*
   (b) *Work Zone Duration (days): 12*
   (c) *Work Zone Capacity (vphpl): 1,510 (from Table 6)*
   (d) *Work Zone Speed Limit (mph): 60*
   (e) *No of Lanes Open in Each Direction: 1 (two out of the three lanes closed for single-lane paving)*
   (f) *Work Zone Hours: 20 for "Start" and 6 for "End" (10-Hour closure of "Inbound" or "Outbound" traffic only).*

2) *10-year Rehab in year 5: [to be entered under "Rehabilitation 1" tab of "Alternative 1 Form" of RealCost (Figure 11)]*

   (a) *Work Zone Length (miles): 1.4 (assumed value based upon the roadway configuration and the daily production rate)*
   (b) *Work Zone Duration (days): 51*
   (c) *Work Zone Capacity (vphpl): 1,510 (from Table 6)*
   (d) *Work Zone Speed Limit (mph): 60*
   (e) *No of Lanes Open in Each Direction: 1 (two out of the three lanes closed for single-lane paving)*
   (f) *Work Zone Hours: 20 for "Start" and 24 for "End" on first line and 0 for "Start" and "06" for "End" on second line. This is because the closure actually takes place on the evening of one day and the morning of the next..*

3) *5-year CAPM in year 15: [to be entered under "Initial Construction" tab of "Alternative 1 Form" of RealCost (Figure 11)]*

   - *All work zone inputs are assumed to be same as those for the initial construction.*

4) *10-year Rehab in year 20: [to be entered under "Rehabilitation 3" tab of "Alternative 1 Form" of RealCost (Figure 11)]*

   - *All work zone inputs are assumed to be the same as those for the 10-year Rehab in year 5.*

Once all the alternative-level inputs have been entered into the Alternative 1 or Alternative 2 forms, click the "Ok" button to return to the "Switchboard" or "Cancel" button to start over.

Note:

Be sure to provide the minimum information in all six "Rehabilitation" tabs to avoid an error message. The minimum inputs are: Activity Service Life, Work Zone Length, Work Zone Capacity, Work Zone Speed Limit, and No. of Lanes Open in Each Direction During Work Zone. Zero can be entered in the remaining input fields.

3.4 Input Warnings

To see a list of missing or potentially erroneous data, click the "Show Warnings" button in the "Switchboard" (Figure 12). It is recommended that you verify your inputs by clicking this button before running the analysis.

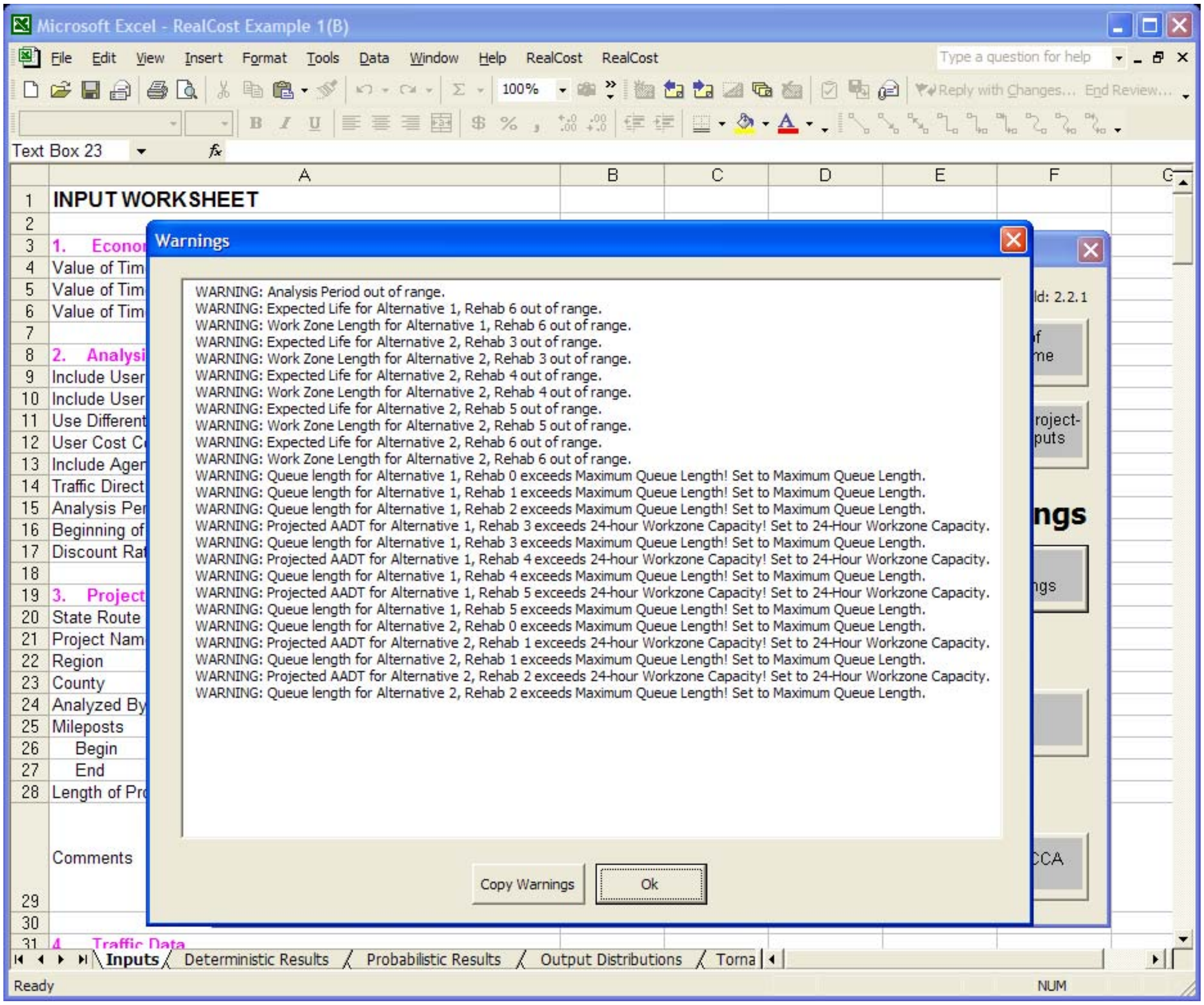


Figure 12. Input Warnings

3.4 Simulation and Outputs

The "Simulation and Outputs" section of the *RealCost* Switchboard (Figure 4) includes buttons to view deterministic life-cycle cost results and buttons to run simulations of probabilistic inputs.

- *Deterministic Results*: Click this button to have *RealCost* calculate and display deterministic values for both agency and user costs based upon the deterministic inputs. The "Deterministic Results Form" (Figure 13) provides a direct link ("Go to Worksheet" button) to the "Deterministic Results Excel Worksheet" that contains all the information needed to investigate the deterministic results.

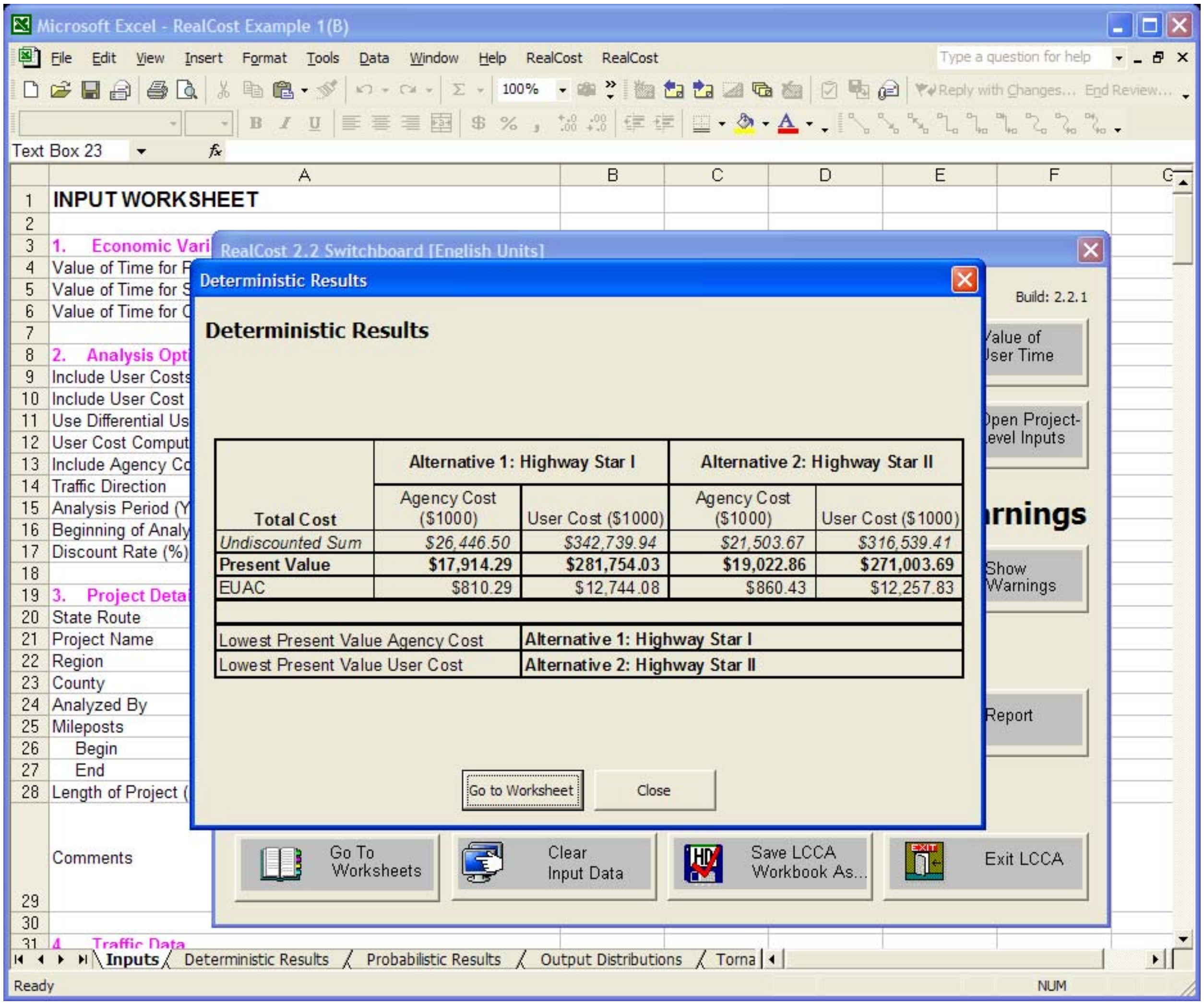
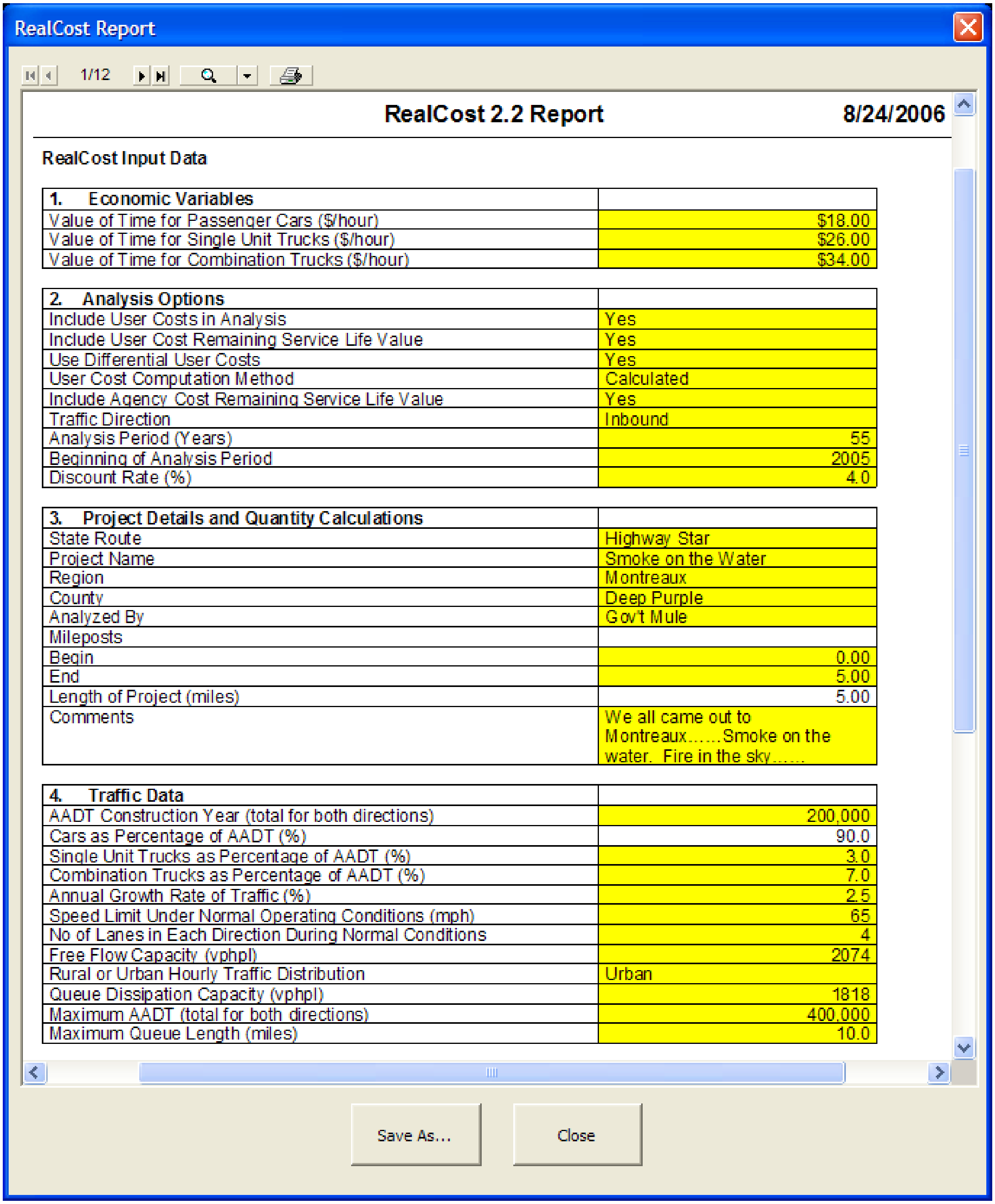


Figure 13. Deterministic Results Form

- *Simulation*: Clicking this button will initiate Monte Carlo simulation of probabilistic inputs. At present it is not being used.
- *Probabilistic Results*: Clicking this button will display probabilistic results. At present it is not being used.
- *Reports*: Click this button to have *RealCost* produce a twelve-page report (Figure 14) that shows inputs and results. The last two pages include results of the probabilistic analysis, and they will be blank if no probabilistic inputs are entered.



RealCost 2.2 Report 8/24/2006

RealCost Input Data

1. Economic Variables	
Value of Time for Passenger Cars ($/hour)	$18.00
Value of Time for Single Unit Trucks ($/hour)	$26.00
Value of Time for Combination Trucks ($/hour)	$34.00

2. Analysis Options	
Include User Costs in Analysis	Yes
Include User Cost Remaining Service Life Value	Yes
Use Differential User Costs	Yes
User Cost Computation Method	Calculated
Include Agency Cost Remaining Service Life Value	Yes
Traffic Direction	Inbound
Analysis Period (Years)	55
Beginning of Analysis Period	2005
Discount Rate (%)	4.0

3. Project Details and Quantity Calculations	
State Route	Highway Star
Project Name	Smoke on the Water
Region	Montreaux
County	Deep Purple
Analyzed By	Gov't Mule
Mileposts	
Begin	0.00
End	5.00
Length of Project (miles)	5.00
Comments	We all came out to Montreaux……Smoke on the water. Fire in the sky……

4. Traffic Data	
AADT Construction Year (total for both directions)	200,000
Cars as Percentage of AADT (%)	90.0
Single Unit Trucks as Percentage of AADT (%)	3.0
Combination Trucks as Percentage of AADT (%)	7.0
Annual Growth Rate of Traffic (%)	2.5
Speed Limit Under Normal Operating Conditions (mph)	65
No of Lanes in Each Direction During Normal Conditions	4
Free Flow Capacity (vphpl)	2074
Rural or Urban Hourly Traffic Distribution	Urban
Queue Dissipation Capacity (vphpl)	1818
Maximum AADT (total for both directions)	400,000
Maximum Queue Length (miles)	10.0

Figure 14. *RealCost* Report

3.5 Administrative Functions

The "Administrative Functions" section of the *RealCost* Switchboard (Figure 4) allows the user to save, clear, and retrieve data, and to close the "Switchboard" or *RealCost*.

- *Go to Worksheets*: Clicking this button will allow direct access to any input or result worksheets.
- *Clear Input Data*: Clicking this button will clear from the software project-level inputs, alternative-level inputs, and results.
- *Save LCCA Workbook As..*: Clicking this button allows you to save the entire Excel workbook, including all inputs and results worksheets, under a name you specify.
- *Exit LCCA*: Clicking this button will close *RealCost*.

CHAPTER 4 – ANALYZING LCCA RESULTS

Although life cycle costs are reported in dollars, the results should viewed as a comparison of cost effectiveness between the alternatives analyzed. The costs generated by *RealCost* should not be interpreted or viewed as the ACTUAL dollars it would cost the Department or the public.

The purpose of the life cycle cost analysis is to compare to viable pavement strategies to see which has the most cost and economic benefit to the state over the analysis period. To do this requires estimating each alternative using the same methodology and assumptions to provide an equal (“apples to apples”) comparison. The theory is that if any changes over time that differ from the assumptions will effect both alternatives equally and therefore not change which one was more cost effective. To be sure that the output is reasonable and a good comparison, the results should be analyzed for:

- Input errors
- Excessive cost differences between alternatives
- Reality check. (Do the inputs and outputs make sense.)

Analyzing LCCA results involves examining and interpreting the *RealCost* outputs for alternative pavement designs. There are many factors to consider when doing the comparison. For example, one of the first things to consider might be the contribution of user costs to the total life-cycle cost for the project alternatives. For projects proposed on highway corridors with large traffic volumes, user costs can be significantly greater than agency costs. User costs for each alternative should be compared to determine if there is a disproportionately high or low impact on users.

If the lowest agency cost alternative has a disproportionately high user cost, this information should be used either to revisit the alternative's traffic management aspect or to reconsider an alternative that might have somewhat higher agency costs but much lower user costs.

The lowest agency cost alternative may not necessarily be the best solution since there are also other factors that should be addressed, such as safety, air pollution, non-user, and business impacts resulting from reduced or restricted traffic. If a higher life-cycle cost alternative is selected over a lower cost one, the justification should be documented in the PID, PR, or other appropriate project document. In these instances, a design exception may be required (see the HDM Topic 612). However, for analysis purposes, project alternatives whose life-cycle costs are within 10 percent of each other are considered to be equivalent: either one can be considered to have the lower life-cycle cost.

REFERENCES

1. Federal Highway Administration, "Life-Cycle Cost Analysis in Pavement Design," FHWA-SA-98-079, Pavement Division Interim Technical Bulletin, September 1998.

2. Federal Highway Administration, Life-Cycle Cost Analysis, *RealCost* User Manual, August 2004.

3. Federal Highway Administration, "Life Cycle Cost Analysis Primer," August 2002.

4. California Department of Transportation, "2004 State of the Pavement," Division of Maintenance, Office of Roadway Rehabilitation and Roadway Maintenance, July 2005.

5. California Department of Transportation, "Highway Design Manual," Sixth Edition, September 2006.

6. California Department of Transportation, "Historical Cost Analysis of Capital Outlay Support for FYs 1998 to 2002," Division of Project Management, Office of Project Workload and Data Management, May 2005.

7. Washington State Department of Transportation, "Pavement Type Selection Protocol," Environmental and Engineering Program Division, January 2005.

APPENDIX 1: GLOSSARY AND LIST OF ACRONYMS

A. Glossary

Analysis Period: the period of time during which the initial and any future costs for the project alternatives will be evaluated.

Activity Service Life: the time period that the asset will remain viable for public use (at or above a minimum level of service).

CApital Preventive Maintenance (CAPM): CAPM consists of work performed to preserve the existing pavement structure utilizing strategies that preserve or extend pavement service life. See HDM Index 603.2 and the CAPM Guidelines for further information.

Composite Pavement: pavements comprised of both rigid and flexible layers. Currently, for purposes of the procedures in the HDM, only flexible over rigid composite pavements are considered composite pavements.

Continuously Reinforced Concrete Pavement (CRCP): one type of rigid pavement with reinforcing steel and no transverse joints except at construction joint or paving stops for more than 30 minutes. CRCPs are reinforced in the longitudinal direction, and additional steel is also used in the transverse direction to hold the longitudinal steel. Due to the continuous reinforcement in the longitudinal direction, the pavement develops transverse cracks spaced at close intervals. These cracks develop due to changes in the concrete volume, restrained by the longitudinal reinforcement steel, resulting from moisture and temperature variation. Crack width can affect the rate of corrosion of the reinforcing steel at the crack locations when water or de-icing salts (if used) penetrate the cracks. In a well-designed CRCP, the longitudinal steel should be able to keep the transverse cracks tightly closed.

Crack, Seat, and Flexible Overlay (CSO): A rehabilitation strategy for rigid pavements. CSO practice requires the contractor to crack and seat the rigid pavement slabs, and place a flexible overlay with a pavement reinforcing fabric (PRF) interlayer.

Flexible Pavement: Pavements engineered to transmit and distribute traffic loads to the underlying layers. The highest quality layer is the surface course (generally asphalt binder mixes), which may or may not incorporate underlying layers of a base and a subbase. These types of pavements are called "flexible" because the total pavement structure bends or flexes to accommodate deflection bending under traffic loads.

Hot Mix Asphalt (HMA): formerly known as asphalt concrete (AC), is a graded asphalt concrete mixture (aggregate and asphalt binder) containing a small percentage of voids which is used primarily as a surface course to provide the structural strength needed to distribute loads to underlying layers of the pavement structure.

Hot Mix Asphalt with Open Graded Frictional Course (HMA w/ OGFC): an open graded asphalt concrete wearing course on top of a graded asphalt concrete mixture (aggregate and asphalt binder) containing a small percentage of voids which is used primarily as a surface course to provide the structural strength needed to distribute loads to underlying layers of the pavement structure.

Hot Mix Asphalt with Rubberized Asphalt Concrete (HMA w/ RAC): is a rubberized asphalt concrete wearing course on top of a graded asphalt concrete mixture (aggregate and asphalt binder) containing a small percentage of voids which is used primarily as a surface course to provide the structural strength needed to distribute loads to underlying layers of the pavement structure.

Jointed Plain Concrete Pavement (JPCP): one type of rigid pavement, also referred to as Portland Cement Concrete Pavement (PCCP), constructed with longitudinal and transverse joints. JPCPs do not contain steel reinforcement, other than tie bars and dowel bars. JPCPs are doweled in the transverse joints to improve load transfer and prevent faulting of the slabs from occurring. Tie bars are used in the longitudinal joints to hold adjoining slabs together.

Lane Replacement: the removal of individual slabs (or panels) of concrete pavement with the total length of consecutive slabs is greater than 100 feet.

Maintenance Service Level (MSL): For maintenance programming purposes, the State Highway System has been classified as Class 1, 2, and 3 highways based on the MSL descriptive definitions:

- MSL 1 – Contains route segments in urban areas functionally classified as Interstate, Other Freeway/Expressway, or Other Principal Arterial. In rural areas, the MSL 1 designation contains route segments functionally classified as Interstate or Other Principal Arterial

- MSL 2 – Contains route segments classified as an Other Freeway/Expressway, or Other Principal Arterial not in MSL 1, and route segments functionally classified as minor arterials not in MSL 3
- MSL 3 – Indicates a route or route segment with the lowest maintenance priority. Typically, MSL 3 contains route segments functionally classified as major or minor collectors and local roads, route segments with relatively low traffic volumes. Route segments where route continuity is necessary are also assigned MSL 3 designation.

<u>Pavement:</u> The planned, engineered system of layers of specified materials (typically consisting of surface course, base, and subbase) placed over the subgrade soil to support the cumulative traffic loading anticipated during the design life of the pavement. The pavement is also referred to as the pavement structure and has been referred to as pavement structural section.

<u>Open Graded Frictional Course (OGFC):</u> Formerly known as open graded asphalt concrete (OGAC), OGFC is a wearing course mix consisting of asphalt binder and aggregate with relatively uniform grading and little or no fine aggregate and mineral filler. OGFC is designed to have a large number of void spaces in the compacted mix as compared to hot mix asphalt.

<u>Pavement Design Life:</u> The period of time that a newly constructed or rehabilitated pavement is engineered to perform before reaching a condition that requires pavement (CAPM). Also known as terminal serviceability. The selected pavement design life varies depending on the characteristics of the highway facility, the objective of the project, and projected traffic volume and loading. See HDM Topic 612 for more information.

<u>Rapid Strength Concrete:</u> Use to replace concrete slabs and lanes during short construction windows where conventional portland cement concrete will not have time to cure and gain strength.

<u>Rehabilitation:</u> work undertaken to extend the service life of an existing facility. This includes placement of additional surfacing and/or other work necessary to return an existing roadway, including shoulders, to a condition of structural or functional adequacy, for the specified service life. This might include the partial or complete removal and replacement of portions of the

pavement structure. Rehabilitation work is divided into pavement rehabilitation activities and roadway rehabilitation activities

Remaining Service Life Value (RSV): The value of the activity service life that remains in a project alternative beyond the end of the analysis period.

Rigid Pavement: pavements with a rigid surface course (typically Portland cement concrete or a variety of specialty cement mixes for rapid strength concretes), which may incorporate underlying layers of stabilized or unstabilized base or subbase materials. These types of pavements rely on the substantially higher stiffness rigid slab to distribute the traffic loads over a relatively wide area of underlying layers and the subgrade. Some rigid slabs have reinforcing steel to help resist cracking due to temperature changes and repeated loading.

Rubberized Asphalt Concrete (RAC): a material produced for hot mix applications by mixing either asphalt rubber or rubberized asphalt binder with graded aggregate. RAC may be dense- (RAC-D), gap- (RAC-G), or open- (RAC-O) graded.

Rubberized Asphalt Concrete-Gap Graded (RAC-G): a gap graded mixture of crushed coarse and fine aggregate, and of paving asphalt that are combined with specified percentages of granulated (crumb) reclaimed rubber. RAC-G can be used as either a surface course or a non-structural wearing course.

Rubberized Asphalt Concrete Open Graded (RAC-O): same as RAC-G, except RAC-O is used only as a non-structural wearing course.

Slab Replacement: the removal of individual slabs (or panels) of concrete pavement with the total length of consecutive slabs is 100 feet or less.

Terminal Serviceability: the condition of the pavement at the end of its pavement design life. In California, this is defined as the pavement rehabilitation (CAPM).

B. List of Acronyms

BCA	=	Benefit-Cost Analysis
Caltrans	=	California Department of Transportation
Cal-B/C	=	California Life-Cycle Benefit/Cost Model
CAPM	=	CApital Preventive Maintenance
CRCP	=	Continuously Reinforced Concrete Pavement
FHWA	=	Federal Highway Administration
HDM	=	Highway Design Manual
HMA	=	Hot Mixed Asphalt
JPCP	=	Jointed Plain Concrete Pavement
LCCA	=	Life-Cycle Cost Analysis
M&R	=	Maintenance & Rehabilitation/Reconstruction
MSL	=	Maintenance Service Level
OGFC	=	Open Graded Friction Course
PA&ED	=	Project Approval & Environmental Document
pcphpl	=	passenger cars per hour per lane
PDPM	=	Project Development Procedures Manual
PID	=	Project Initiation Document
PR	=	Project Report
RAC	=	Rubberized Asphalt Concrete
RAC-O	=	Rubberized Asphalt ConcreteOpen Graded
RSL	=	Remaining Service Life
TI	=	Traffic Index

vph	=	vehicles per hour
vphpl	=	vehicles per hour per lane

APPENDIX 2: LIST OF LIMITATIONS TO AND BUGS IN *REALCOST*

A. Bug/Question(s)

1) Program appears to calculate salvage value based on a round-down if activity life is a decimal of less than 0.5 year.

B. Limitation(s)

1) *RealCost* only allows for six subsequent maintenance/rehabilitation actions in life-cycle of an alternative.
2) *RealCost* can only analyze two alternatives at once. If needing to analyze 3 or more alternatives will need to run the program more than once and then physically compare the differences.

APPENDIX 3: PRODUCTIVITY ESTIMATES OF TYPICAL M&R STRATEGIES

Table 10. Production Estimates of CAPM Strategies for Flexible Pavements

Final Surface Type	Future M&R Alternative	Pvmt Design Life (years)	Maint. Service Level	Description	Average Lane-mile Completed Per Closure[1]: 6-Hour Closure[2]	10-Hour Closure[3]	Continuous Closure: 16 hour/day Operation[5]	Continuous Closure: 24 hour/day Operation[5]	Weekend Closure[6] (55-Hour)
CapM (Pavement Rehabilitation)									
HMA	HMA Overlay	5	1,2,3	0.15' HMA	0.79	1.87	3.21	5.35	19.62
		10	1,2,3	0.25' HMA	0.48	1.12	1.93	3.22	11.82
	Mill & Overlay with HMA	5	1,2,3	0.15' Mill plus 0.15' HMA		0.68	1.25	2.16	6.51
				* 0.15' Mill	0.56	1.29	2.21	3.71	9.72
				* 0.15' HMA	0.79	1.87	3.21	5.35	19.62
		10	1,2,3	0.25' Mill plus 0.25' HMA		0.40	0.85	1.47	4.54
				* 0.25' Mill	0.43	0.99	1.70	2.85	7.44
				* 0.25' HMA	0.48	1.12	1.93	3.22	11.82
HMA w/ OGFC	HMA w/ OGFC Overlay	5	1,2,3	0.10' OGFC over 0.15' HMA	0.28	1.08	1.90	3.17	18.73
				* 0.15' HMA	0.79	1.87	3.21	5.35	19.62
				* 0.10' OGFC	1.18	2.79	4.80	8.00	29.28
		10	1,2,3	0.10' OGFC over 0.25' HMA		0.66	1.35	2.27	8.36
				* 0.25' HMA	0.48	1.12	1.93	3.22	11.82
				* 0.10' OGFC	1.18	2.79	4.80	8.00	29.28
	Mill & Overlay with HMA w/ OGFC	5	1,2,3	0.25' Mill plus 0.10' OGFC over 0.15' HMA		0.40	0.84	1.45	4.51
				* 0.25' Mill	0.43	0.99	1.70	2.85	7.44
				* 0.15' HMA	0.79	1.87	3.21	5.35	19.62
				* 0.10' OGFC	1.18	2.79	4.80	8.00	29.28
		10	1,2,3	0.35' Mill plus 0.10' OGFC over 0.25' HMA			0.53	1.05	3.36
				* 0.35' Mill	0.33	0.75	1.30	2.17	5.69
				* 0.25' HMA	0.48	1.12	1.93	3.22	11.82
				* 0.10' OGFC	1.18	2.79	4.80	8.00	29.28
HMA w/ RAC	HMA w/ RAC Overlay	5	1,2,3	0.10' RAC over 0.15' HMA	0.28	1.08	1.90	3.17	11.64
				* 0.15' HMA	0.79	1.87	3.21	5.35	19.62
				* 0.10' RAC	1.18	2.79	4.80	8.00	29.28
		10	1,2,3	0.10' RAC over 0.25' HMA		0.66	1.35	2.27	8.36
				* 0.25' HMA	0.48	1.12	1.93	3.22	11.82
				* 0.10' RAC	1.18	2.79	4.80	8.00	29.28
	Mill & Overlay with HMA w/ RAC	5	1,2,3	0.25' Mill plus 0.10' RAC over 0.15' HMA		0.40	0.84	1.45	4.51
				* 0.25' Mill	0.43	0.99	1.70	2.85	7.44
				* 0.15' HMA	0.79	1.87	3.21	5.35	19.62
				* 0.10' RAC	1.18	2.79	4.80	8.00	29.28
		10	1,2,3	0.35' Mill plus 0.10' RAC over 0.25' HMA			0.53	1.05	3.36
				* 0.35' Mill	0.33	0.75	1.30	2.17	5.69
				* 0.25' HMA	0.79	1.87	3.21	5.35	11.82
				* 0.10' RAC	1.18	2.79	4.80	8.00	29.28
RAC-G	RAC-G Overlay	5	1,2,3	0.10' RAC-G	1.18	2.79	4.80	8.00	29.28
		10	1,2,3	0.15' RAC-G	0.79	1.87	3.21	5.35	19.62
	Mill & Overlay with RAC-G	5	1,2,3	0.10' Mill plus 0.10' RAC-G	0.27	0.86	1.58	2.70	8.10
				* 0.10' Mill	0.64	1.47	2.53	4.24	11.09
				* 0.10' RAC-G	1.18	2.79	4.80	8.00	29.28
		10	1,2,3	0.20' Mill plus 0.20' RAC-G		0.53	1.02	1.76	5.39
				* 0.20' Mill	0.49	1.13	1.94	3.25	8.51
				* 0.20' RAC-G	0.58	1.40	1.44	4.02	14.76
RAC-G w/ RAC-O	RAC-G w/ RAC-O Overlay	10	1,2,3	0.10' RAC-O over 0.10' RAC-G	0.55	1.35	1.41	3.95	14.48
				* 0.10' RAC-G	1.18	2.79	4.80	8.00	29.28
				* 0.10' RAC-O	1.18	2.79	4.80	8.00	29.28
	Mill & Overlay with RAC-G w/ RAC-O	10	1,2,3	0.20' Mill plus 0.10' RAC-O over 0.10' RAC-G		0.68	1.25	2.16	5.34
				* 0.20' Mill	0.49	1.13	1.94	3.25	8.51
				* 0.10' RAC-G	1.18	2.79	4.80	8.00	29.28
				* 0.10' RAC-O	1.18	2.79	4.80	8.00	29.28

Table 11. Production Estimates of Rehabilitation Strategies for Flexible Pavements

Final Surface Type	Future M&R Alternative	Pvmt Design Life (years)	Maint. Service Level	Description	Average Lane-mile Completed Per Closure(1)				
					6-Hour Closure(2)	10-Hour Closure(3)	Continuous Closure		Weekend Closure(6) (55-Hour)
							16 hour/day Operation(5)	24 hour/day Operation(5)	
Roadway Rehabilitation									
HMA	HMA Overlay	10	1,2,3	0.35' HMA (in two lifts)		0.66	1.35	2.27	8.36
				* 0.25' HMA	0.48	1.12	1.93	3.22	11.82
				* 0.10' HMA	1.18	2.79	4.80	8.00	29.28
		20	1,2,3	0.50' HMA (in two lifts)		0.33	0.75	1.60	5.87
				* 0.25' HMA	0.48	1.12	1.93	3.22	11.82
				* 0.25' HMA	0.48	1.12	1.93	3.22	11.82
	Mill & Overlay with HMA	10	1,2,3	0.35' Mill plus 0.35' HMA (in two lifts)			0.53	1.05	3.36
				* 0.35' Mill	0.33	0.75	1.30	2.17	5.69
				* 0.35' HMA (in two lifts)		0.66	1.35	2.27	8.36
				* 0.25' HMA	0.48	1.12	1.93	3.22	11.82
				* 0.10' HMA	1.18	2.79	4.80	8.00	29.28
		20	1,2,3	0.50' Mill plus 0.50' HMA (in two lifts)			0.30	0.73	2.27
				* 0.50' Mill		0.50	0.87	1.45	3.80
				* 0.25' HMA	0.48	1.12	1.93	3.22	11.82
				* 0.25' HMA	0.48	1.12	1.93	3.22	11.82
HMA w/ OGFC	HMA w/ OGFC Overlay	10	1,2,3	0.10' OGFC over 0.35' HMA (in two lifts)		0.52	0.80	1.75	5.82
				* 0.25' HMA	0.48	1.12	1.93	3.22	11.82
				* 0.10' HMA	1.18	2.79	4.80	8.00	29.28
				* 0.10' OGFC	1.18	2.79	4.80	8.00	29.28
		20	1,2,3	0.10' OGFC over 0.50' HMA (in two lifts)			0.52	1.30	4.87
				* 0.25' HMA	0.48	1.12	1.93	3.22	11.82
				* 0.25' HMA	0.48	1.12	1.93	3.22	11.82
				* 0.10' OGFC	1.18	2.79	4.80	8.00	29.28
	Mill & Overlay with HMA w/ OGFC	10	1,2,3	0.45' Mill plus 0.10' OGFC over 0.35' HMA (in two lifts)			0.28	0.71	2.55
				* 0.45' Mill	0.25	0.58	0.99	1.66	4.34
				* 0.25' HMA	0.48	1.12	1.93	3.22	11.82
				* 0.10' HMA	1.18	2.79	4.80	8.00	29.28
				* 0.10' OGFC	1.18	2.79	4.80	8.00	29.28
		20	1,2,3	0.60' Mill plus 0.10' OGFC over 0.50' HMA (in two lifts)				0.81	1.76
				* 0.60' Mill		0.39	0.66	1.10	2.89
				* 0.25' HMA	0.48	1.12	1.93	3.22	11.82
				* 0.25' HMA	0.48	1.12	1.93	3.22	11.82
				* 0.10' OGFC	1.18	2.79	4.80	8.00	29.28
HMA w/ RAC	HMA w/ RAC Overlay	10	1,2,3	0.10' RAC over 0.35' HMA (in two lifts)		0.52	0.80	1.75	5.82
				* 0.25' HMA	0.48	1.12	1.93	3.22	11.82
				* 0.10' HMA	1.18	2.79	4.80	8.00	29.28
				* 0.10' RAC	1.18	2.79	4.80	8.00	29.28
		20	1,2,3	0.10' RAC over 0.50' HMA (in two lifts)			0.52	1.30	4.87
				* 0.25' HMA	0.48	1.12	1.93	3.22	11.82
				* 0.25' HMA	0.48	1.12	1.93	3.22	11.82
				* 0.10' RAC	1.18	2.79	4.80	8.00	29.28
	Mill & Overlay with HMA w/ RAC	10	1,2,3	0.45' Mill plus 0.10' RAC over 0.35' HMA (in two lifts)			0.28	0.71	2.55
				* 0.45' Mill	0.25	0.58	0.99	1.66	4.34
				* 0.25' HMA	0.48	1.12	1.93	3.22	11.82
				* 0.10' HMA	1.18	2.79	4.80	8.00	29.28
				* 0.10' RAC	1.18	2.79	4.80	8.00	29.28
		20	1,2,3	0.60' Mill plus 0.10' RAC over 0.50' HMA (in two lifts)				0.50	1.76
				* 0.60' Mill		0.39	0.66	1.10	2.89
				* 0.25' HMA	0.48	1.12	1.93	3.22	11.82
				* 0.25' HMA	0.48	1.12	1.93	3.22	11.82
				* 0.10' RAC	1.18	2.79	4.80	8.00	29.28
RAC-G	RAC-G Overlay	10	1,2,3	0.15' RAC-G	0.79	1.87	3.21	5.35	19.62
		20	1,2,3	0.25' RAC-G	0.48	1.12	1.93	3.22	11.82
	Mill & Overlay with RAC-G	10	1,2,3	0.15' Mill plus 0.15' RAC-G		0.68	1.25	2.16	6.51
				* 0.15' Mill	0.56	1.29	2.21	3.71	9.72
				* 0.15' RAC-G	0.79	1.87	3.21	5.35	19.62
		20	1,2,3	0.25' Mill plus 0.25' RAC-G		0.40	0.85	1.47	4.54
				* 0.25' Mill	0.43	0.99	1.70	2.85	7.44
				* 0.25' RAC-G	0.48	1.12	1.93	3.22	11.82
RAC-G w/ RAC-O	RAC-G w/ RAC-O Overlay	10	1,2,3	0.10' RAC-O over 0.15' RAC-G	0.28	1.08	1.90	3.17	11.64
				* 0.15' RAC-G	0.79	1.87	3.21	5.35	19.62
				* 0.10' RAC-O	1.18	2.79	4.80	8.00	29.28
		20	1,2,3	0.10' RAC-O over 0.25' RAC-G		0.66	1.35	2.27	8.36
				* 0.25' RAC-G	0.48	1.12	1.93	3.22	11.82
				* 0.10' RAC-O	1.18	2.79	4.80	8.00	29.28
	Mill & Overlay with RAC-G w/ RAC-O	10	1,2,3	0.25' Mill plus 0.10' RAC-O over 0.15' RAC-G		0.4	0.84	1.45	4.54
				* 0.25' Mill	0.43	0.99	1.70	2.85	7.44
				* 0.15' RAC-G	0.79	1.87	3.21	5.35	19.62
				* 0.10' RAC-O	1.18	2.79	4.80	8.00	29.28
		20	1,2,3	0.35' Mill plus 0.10' RAC-O over 0.25' RAC-G			0.53	1.05	3.36
				* 0.35' Mill	0.33	0.75	1.30	2.17	5.69
				* 0.25' RAC-G	0.48	1.12	1.93	3.22	11.82
				* 0.10' RAC-O	1.18	2.79	4.80	8.00	29.28

Table 12. Production Estimates of CAPM Strategies for Rigid Pavements

Final Surface Type	Future M&R Alternative	Pvmt. Design Life (years)	Maint. Service Level	Description	Average Lane-mile Completed Per Closure[1]				
					6-Hour Closure[2]	10-Hour Closure[3]	Continuous Closure: 16 hour/day Operation[4]	Continuous Closure: 24 hour/day Operation[5]	Weekend Closure (55-Hour)
CapM (Pavement Rehabilitation)									
Flexible	Flexible Overlay	5	1,2,3	0.15' Flexible	0.79	1.87	3.21	5.35	19.62
		10	1,2,3	0.25' Flexible	0.25	1.12	1.93	3.22	11.82
	Flexible Overlay w/ Slab Replacements	5	1,2,3	2% Slab Replacements w/ FSHCC (0.67') plus 0.15' Flexible Overlay	0.31	1.48	2.67	4.49	16.42
				* 0.67' FSHCC Slab Replacements	0.01	0.14	0.32	0.56	2.01
				- 0.67' Slab Demolition	0.17	0.34	0.56	0.85	2.17
				- 0.67' FSHCC Slab Paving	0.08	0.34	0.72	1.22	3.50
				* 0.15' Flexible	0.79	1.87	3.21	5.35	19.62
		5	1,2,3	2% Slab Replacements w/ RSC (0.67') plus 0.15' Flexible Overlay			1.41	3.91	15.87
				* 0.67' RSC Slab Replacements			0.05	0.29	1.66
				- 0.67' Slab Demolition	0.17	0.34	0.56	0.85	2.17
				- 0.67' RSC Slab Paving			0.22	0.72	2.91
				* 0.15' Flexible	0.79	1.87	3.21	5.35	19.62
		10	1,2,3	2% Slab Replacements w/ FSHCC (0.67') plus 0.25' Flexible Overlay	0.17	0.97	1.72	2.89	10.58
				* 0.67' FSHCC Slab Replacements	0.01	0.14	0.32	0.56	2.01
				- 0.67' Slab Demolition	0.17	0.34	0.56	0.85	2.17
				- 0.67' FSHCC Slab Paving	0.08	0.34	0.72	1.22	3.50
				* 0.25' Flexible	0.25	1.12	1.93	3.22	11.82
		10	1,2,3	2% Slab Replacements w/ RSC (0.67') plus 0.25' Flexible Overlay			1.09	2.63	10.35
				* 0.67' RSC Slab Replacements			0.05	0.29	1.66
				- 0.67' Slab Demolition	0.17	0.34	0.56	0.85	2.17
				- 0.67' RSC Slab Paving			0.22	0.72	2.91
				* 0.25' Flexible	0.25	1.12	1.93	3.22	11.82
	Conc. Pvmt Rehab A[1]	5	1,2,3	7% Slab Replacements w/ FSHCC (0.67') plus Pavement Grinding	0.14	2.00	4.57	8.00	28.71
				* 0.67' Slab Demolition plus Pavement Grinding	0.17	0.34	0.56	0.85	2.17
				* 0.67' FSHCC Slab Paving	0.08	0.34	0.72	1.22	3.50
		5	1,2,3	7% Slab Replacements w/ RSC (0.67') plus Pavement Grinding			0.71	4.14	23.71
				* 0.67' Slab Demolition plus Pavement Grinding	0.17	0.34	0.56	0.85	2.17
				* 0.67' RSC Slab Paving			0.22	0.72	2.91
	Conc. Pvmt Rehab B[2]	5	1,2,3	5% Slab Replacements w/ FSHCC (0.67') plus Pavement Grinding	0.20	2.80	6.40	11.20	40.20
				* 0.67' Slab Demolition plus Pavement Grinding	0.17	0.34	0.56	0.85	2.17
				* 0.67' FSHCC Slab Paving	0.08	0.34	0.72	1.22	3.50
		5	1,2,3	5% Slab Replacements (0.67' RSC Slab) plus Pavement Grinding			1.00	5.80	33.20
				* 0.67' Slab Demolition plus Pavement Grinding	0.17	0.34	0.56	0.85	2.17
				* 0.67' RSC Slab Paving			0.22	0.72	2.91
Jointed Plain Concrete Pavement (JPCP)	Conc. Pvmt Rehab C[3]	10	1,2,3	2% Slab Replacements w/ FSHCC (0.67') plus Pavement Grinding	0.50	7.00	16.00	28.00	
				* 0.67' Slab Demolition plus Pavement Grinding	0.17	0.34	0.56	0.85	2.17
				* 0.67' FSHCC Slab Paving	0.08	0.34	0.72	1.22	3.50
		10	1,2,3	2% Slab Replacements w/ RSC (0.67') plus Pavement Grinding			2.50	14.50	
				* 0.67' Slab Demolition plus Pavement Grinding	0.17	0.34	0.56	0.85	2.17
				* 0.67' RSC Slab Paving			0.22	0.72	2.91

Table 13. Production Estimates of Rehabilitation Strategies for Rigid Pavements

Final Surface Type	Future M&R Alternative	Pvmt. Design Life (years)	Maint. Service Level	Description	Average Lane-mile Completed Per Closure[1]				
					6-Hour Closure[2]	10-Hour Closure[3]	Continuous Closure: 16 hour/day Operation[4]	Continuous Closure: 24 hour/day Operation[5]	Weekend Closure (55-Hour)
Roadway Rehabilitation									
Flexible	Flexible Overlay w/ Slab Replacements	10	1,2,3	5% Slab Replacements w/ FSHCC (0.67') plus 0.25' Flexible Overlay	0.11	0.80	1.48	2.50	9.13
				* 0.67' FSHCC Slab Replacements	0.01	0.14	0.32	0.56	2.01
				- 0.67' Slab Demolition	0.17	0.34	0.56	0.85	2.17
				- 0.67' FSHCC Slab Paving	0.08	0.34	0.72	1.22	3.50
				* 0.25' Flexible	0.25	1.12	1.93	3.22	11.82
		10	1,2,3	5% Slab Replacements w/ RSC (0.67') plus 0.25' Flexible Overlay			0.66	2.07	8.72
				* 0.67' RSC Slab Replacements			0.05	0.29	1.66
				- 0.67' Slab Demolition	0.17	0.34	0.56	0.85	2.17
				- 0.67' RSC Slab Paving			0.22	0.72	2.91
				* 0.25' Flexible	0.25	1.12	1.93	3.22	11.82
	Crack, Seat, & Flexible Overlay	10	1,2,3	0.10' Flexible over Pvmt Reinforcing Fabric over 0.25' Flexible		0.66	1.35	2.27	8.36
				* 0.25' Flexible plus Pvmt Reinforcing	0.48	1.12	1.93	3.22	11.82
				* 0.10' Flexible	1.18	2.79	4.80	8.00	29.28
		20	1,2,3	0.10' Flexible over Pvmt Reinforcing Fabric plus 0.35' Flexible (in two lifts)		0.52	0.80	1.75	5.82
				* 0.20' Flexible	0.58	1.40	1.44	4.02	14.76
				* 0.15' Flexible plus Pvmt Reinforcing Fabric	0.79	1.87	3.21	5.35	3.33
				* 0.10' Flexible	1.18	2.79	4.80	8.00	29.28
	Replace with Flexible	20	1,2,3	0.10' Flexible over 0.64' Flexible (in three lifts)			0.74	1.70	6.31
				* 0.25' Flexible	0.48	1.12	1.93	3.22	11.82
				* 0.25' Flexible	0.48	1.12	1.93	3.22	11.82
				* 0.14' Flexible	1.36	3.22	5.54	4.94	9.22
				* 0.10' Flexible	1.18	2.79	4.80	8.00	29.28
		40	1,2,3	0.10' Flexible over 0.95' Flexible (in four lifts)				1.22	3.06
				* 0.25' Flexible	0.48	1.12	1.93	3.22	11.82
				* 0.25' Flexible	0.48	1.12	1.93	3.22	11.82
				* 0.25' Flexible	0.48	1.12	1.93	3.22	11.82
				* 0.20' Flexible	0.58	1.40	1.44	4.02	14.76
				* 0.10' Flexible	1.18	2.79	4.80	8.00	29.28
		20	1,2,3	0.83' FSHCC Slab over 1.00' Treated Base	0.01	0.06	0.13	0.23	0.82
				* 0.67' Slab Demolition	0.17	0.34	0.56	0.85	2.17
				* 1.16' Roadway Excavation	0.18	0.35	0.57	0.87	2.21
				* 1.00' Treated Base	0.17	0.33	0.54	0.82	1.91
				* 0.83' FSHCC Slab	0.07	0.27	0.57	0.97	3.14
Jointed Plain Concrete Pavement (JPCP)	Lane Replacement	20	1,2,3	0.83' RSC Slab over 1.00' Treated Base			0.74	1.70	0.67
				* 0.67' Slab Demolition	0.17	0.34	0.56	0.85	2.17
				* 1.16' Roadway Excavation	0.18	0.35	0.57	0.87	2.21
				* 1.00' Treated Base	0.17	0.33	0.54	0.82	1.91
				* 0.83' RSC Slab			0.17	0.57	2.34
		40	1,2,3	1.00' FSHCC Slab over 1.00' Treated Base	0.01	0.06	0.12	0.21	0.75
				* 0.67' Slab Demolition	0.17	0.34	0.56	0.85	2.17
				* 1.33' Roadway Excavation	0.17	0.32	0.53	0.80	2.08
				* 1.00' Treated Base	0.17	0.33	0.54	0.82	1.91
				* 1.00' FSHCC Slab	0.06	0.23	0.48	0.81	2.35
		40	1,2,3	1.00' RSC Slab over 1.00' Treated Base			0.02	0.11	0.61
				* 0.67' Slab Demolition	0.17	0.34	0.56	0.85	2.17
				* 1.33' Roadway Excavation	0.17	0.32	0.53	0.80	2.08
				* 1.00' Treated Base	0.17	0.33	0.54	0.82	1.91
				* 1.00' RSC Slab			0.15	0.48	1.85
Continuously Reinforced Concrete Pavement (CRCP)	Lane Replacement	20	1,2,3	0.75' RSC Slab over 1.00' Treated Base					
		40	1,2,3	0.83' RSC Slab over 1.00' Treated Base					

APPENDIX 4: TYPICAL PAVEMENT M&R SCHEDULES FOR CALIFORNIA

The following pavement M&R schedules are the consolidation of the "Pavement M&R Decision Trees" (used for activity scheduling) included in Caltrans district offices' ten-year pavement plans. Currently, each Caltrans district office has its own set of pavement decision trees, most of which have different sequences of pavement M&R activities, depending on route class (alternatively known as maintenance service level) and pavement type. The following compilation of California-specific pavement M&R schedules has been developed to simplify the selection of a pavement M&R schedule for the LCCA.

The categorization of these California-specific pavement M&R schedules is based on four factors: the climate region, maintenance service level, existing pavement/final surface type, and initial M&R strategy (i.e., project alternative). The nine climate regions shown in Figure 17 are grouped into the five climate regions (i.e., Coastal, Inland Valley, High Mountain & High Desert, Desert and Low Mountain & South Mountain; see Table 19), and the pavement M&R decisions applicable to these five climate regions are collected from the district offices.

Table 14. Caltrans Climate Region Classification

Caltrans Climate Regions	Climate Regions for Pavement M&R Schedules
North Coast	Coastal
Central Coast	
South Coast	
Inland Valley	Inland Valley
High Mountain	High Mountain and High Desert
High Desert	
Desert	Desert
Low Mountain	Low Mountain and South Mountain
South Mountain	

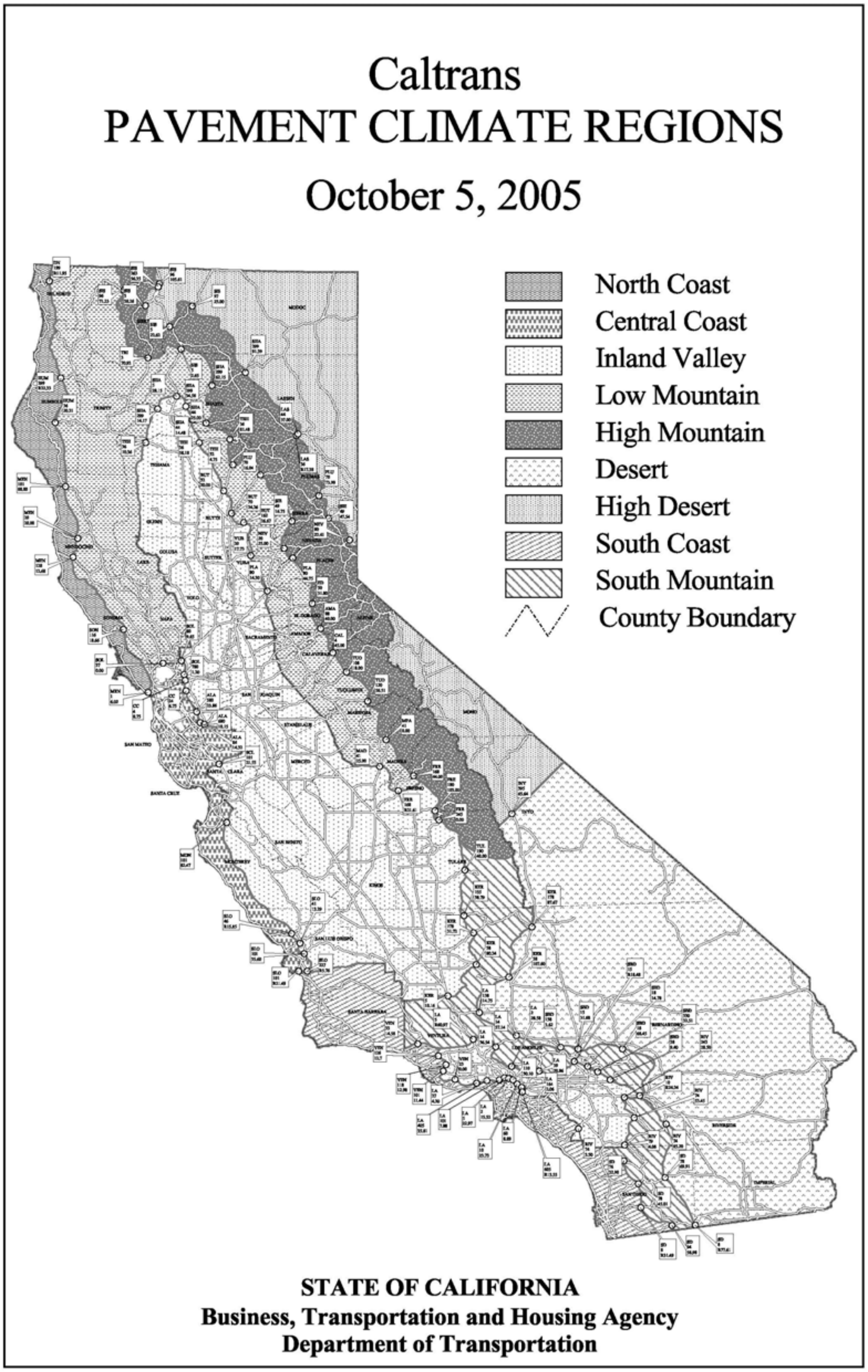


Figure 15. Map of Caltrans Climate Regions

If a pavement decision tree for a particular pavement type is not available for a particular climate region, a similar decision tree from another region is used instead. Since the majority of the district offices do not currently have a pavement decision tree for "New" and "Reconstructed" pavements, the pavement M&R activity sequence and service lives presented for these types of pavements are based on engineering judgment and experience.

Remaining Service Life (RSL)

When doing a widening project with a RSL Alternative that is different from the values in the M&R Schedule Tables, you will need to adjust the life of initial activity to reflect the difference in pavement design life. So for example, if a widening project has a RSL alternative of 26 years, and the life of the initial activity in the M&R schedule for a 20-year pavement design life is 23 years, then the initial activity period that should be entered into *RealCost* should be 29 years.

Projects with Different Pavement Design Lives

When a project has two different pavement design lives within the same project (such as a widening to last 20 years and an overlay of existing that will last only 5 years), the initial costs will need to be divided into two (or more) projects representing the costs to do each component with different pavement design lives and analyzed separately using life-cycle cost analysis. The results of the separate life cycle cost analysis will then need to be combined to produce the overall project result.

Table F1-1 (1)

Hot Mixed Asphalt Pavement Maintenance & Rehabilitation Schedule

(New Construction/Reconstruction at Coastal Climate Region)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year		0		5	10	15	20		25		30		35		40		45		50		55	
New Construction/Reconstruction																										
HMA	20	1,2	1	Year of Action		0					20		25				35		40				50			
				Activity Description		New Const./ Reconst. (20 yr)					CapM (5 yr)		Rehab (10 yr)				CapM (5 yr)		Rehab (10 yr)				CapM (5 yr)			
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	20	1,167				5	1,139	10	2,675			5	1,139	10	2,675			5	1,139		
			2	Year of Action		0					20		25								45		50			
				Activity Description		New Const./ Reconst. (20 yr)					CapM (5 yr)		Rehab (20 yr)								CapM (5 yr)		Rehab (20 yr)			
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	20	1,167				5	1,139	20	1,199							5	1,139	20	1,167		
		3		Year of Action		0					20				30				40		45					
				Activity Description		New Const./ Reconst. (20 yr)					CapM (5 yr)				CapM (5 yr)				CapM (5 yr)		Reconstruct (20 yr)					
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	20	1,167				10	2,675			10	2,675			5	1,096	20	1,167				
HMA w/ OGFC	20	1,2	1	Year of Action		0					22				32						45				55	
				Activity Description		New Const./ Reconst. (20 yr)					CapM w/ OGFC (5 yr)				Rehab w/ OGFC (10 yr)						CapM w/ OGFC (5 yr)				Rehab w/ OGFC (10 yr)	
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	22	1,478				10	3,464			13	2,502					10	3,464			13	2,502
			2	Year of Action		0					22				32								53			
				Activity Description		New Const./ Reconst. (20 yr)					CapM w/ OGFC (5 yr)				Rehab w/ OGFC (20 yr)								CapM w/ OGFC (5 yr)			
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	22	1,478				10	3,464			21	1,522							10	3,464		
		3		Year of Action		0					22				32				42				52			
				Activity Description		New Const./ Reconst. (20 yr)					CapM w/ OGFC (5 yr)				CapM w/ OGFC (5 yr)				CapM w/ OGFC (5 yr)				Reconstruct (20 yr)			
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	22	1,478				10	3,464			10	3,464			10	3,464			22	1,478		
	40	1,2		Year of Action		0													40				50			
				Activity Description		New Const./ Reconst. (40 yr)													CapM w/ OGFC (5 yr)				Rehab w/ OGFC (20 yr)			
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	40	2,921												10	3,464			21	1,522		
		3		Year of Action		0													40				50			
				Activity Description		New Const./ Reconst. (40 yr)													CapM w/ OGFC (5 yr)				CapM w/ OGFC (5 yr)			
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	40	2,921												10	3,464			10	3,464		

Table F1-1 (2)

Hot Mixed Asphalt Pavement Maintenance & Rehabilitation Schedule

(CAPM at Coastal Climate Region)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year		0		5		10		15		20		25		30		35		40		45		50		55	
CapM																													
HMA	5	1,2		Year of Action		0		5				15		20															
				Activity Description		CapM (5 yr)		Rehab (10 yr)				CapM (5 yr)		Rehab (10 yr)															
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	5	1,096	10	2,675			5	1,096	10	2,675														
		3		Year of Action		0		5				15																	
				Activity Description		CapM (5 yr)		CapM (5 yr)				CapM (5 yr)																	
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	5	1,096	10	2,675			10	2,675																
	10	1,2		Year of Action		0				10								30				40							
				Activity Description		CapM (10 yr)				Rehab (20 yr)								CapM (10 yr)				Rehab (20 yr)							
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	10	2,675			20	1,199							10	2,675			20	1,199						
		3		Year of Action		0				10				20				30											
				Activity Description		CapM (10 yr)				CapM (10 yr)				CapM (10 yr)				CapM (10 yr)											
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	10	2,675			10	2,675			10	2,675			10	2,675										
HMA w/ OGFC	5	1,2		Year of Action		0				10						25													
				Activity Description		CapM w/ OGFC (5 yr)				Rehab w/ OGFC (10 yr)						CapM w/ OGFC (5 yr)													
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	10	3,464			15	2,247					10	3,464												
		3		Year of Action		0				10				20															
				Activity Description		CapM w/ OGFC (5 yr)				CapM w/ OGFC (5 yr)				CapM w/ OGFC (5 yr)															
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	10	3,464			10	3,464			10	3,464														
	10	1,2		Year of Action		0						15								36									
				Activity Description		CapM w/ OGFC (10 yr)						Rehab w/ OGFC (20 yr)								CapM w/ OGFC (10 yr)									
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	15	2,247					21	1,522							15	2,247								
		3		Year of Action		0						15						30											
				Activity Description		CapM w/ OGFC (10 yr)						CapM w/ OGFC (10 yr)						CapM w/ OGFC (10 yr)											
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	15	2,247					15	2,247					15	2,247										

Table F1-1 (3)

Hot Mixed Asphalt Pavement Maintenance & Rehabilitation Schedule

(Rehabilitation at Coastal Climate Region)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year	0	5	10	15	20	25	30	35	40	45	50	55
Rehabilitation																
HMA	10	1,2,3		Year of Action	0	9		15		25		35				
				Activity Description	Rehab (10 yr)	CapM (5 yr)		Rehab (10 yr)		CapM (5 yr)		Rehab (10 yr)				
				Activity Service Life (years)	9	6		10		10		10				
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	2,940	895		2,675		2,675		2,675				
HMA	20	1,2,3		Year of Action	0				20	25				45	50	
				Activity Description	Rehab (20 yr)				CapM (5 yr)	Rehab (20 yr)				CapM (5 yr)	Rehab (20 yr)	
				Activity Service Life (years)	20				5	20				5	20	
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	1,199				1,096	$1,199				1,096	1,199	
HMA w/ OGFC	10	1,2,3		Year of Action	0			15		25			40			
				Activity Description	Rehab w/ OGFC (10 yr)			CapM w/ OGFC (5 yr)		Rehab w/ OGFC (10 yr)			CapM w/ OGFC (5 yr)			
				Activity Service Life (years)	15			10		15			10			
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	2,247			3,464		2,247			3,464			
HMA w/ OGFC	20	1,2,3		Year of Action	0				20		30				50	
				Activity Description	Rehab w/ OGFC (20 yr)				CapM w/ OGFC (5 yr)		Rehab w/ OGFC (20 yr)				CapM w/ OGFC (5 yr)	
				Activity Service Life (years)	20				10		20				10	
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	1,699				3,464		1,699				3,464	
HMA w/ OGFC	40	1,2,3		Year of Action	0								40		50	
				Activity Description	Rehab w/ OGFC (40 yr)								CapM (5 yr)		Rehab w/ OGFC (40 yr)	
				Activity Service Life (years)	40								10		40	
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,350								3,436		3,350	

Table F1-2 (1)

Rubberized Asphalt Concrete Pavement Maintenance & Rehabilitation Schedule

(New Construction/Reconstruction at Coastal Climate Region)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year	0	5	10	15	20	25	30	35	40	45	50	55
New Construction/Reconstruction																
RAC	20	1,2	1	Year of Action	0				20	29		39		48		
				Activity Description	New Const./ Reconst. (20 yr)				RAC CapM (5 yr)	RAC Rehab (10 yr)		RAC CapM (5 yr)		RAC Rehab (10 yr)		
				Activity Service Life (years)	20				9	10		9		10		
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	1,846				4,270	3,915		4,270		3,915		
			2	Year of Action	0				20	29				49		
				Activity Description	New Const./ Reconst. (20 yr)				RAC CapM (5 yr)	RAC Rehab (20 yr)				RAC CapM (5 yr)		
				Activity Service Life (years)	20				9	20				9		
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	1,846				4,270	1,846				4,270		
		3		Year of Action	0				20	29			42			55
				Activity Description	New Const./ Reconst. (20 yr)				RAC CapM (5 yr)	RAC CapM (10 yr)			RAC CapM (10 yr)			Reconst. (20 yr)
				Activity Service Life (years)	20				9	13			13			20
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	1,846				4,270	3,057			3,057			1,846
RAC w/ RAC-O	20	1,2	1													
			2													
		3														
	40	1,2														
		3														

Table F1-2 (2)

Rubberized Asphalt Concrete Pavement Maintenance & Rehabilitation Schedule
(CAPM at Coastal Climate Region)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year		0		5		10		15		20	25		30	35		40	45	50	55
CapM																							
RAC	5	1,2		Year of Action		0		9				19			28								
				Activity Description		RAC CapM (5 yr)		RAC Rehab (10 yr)				RAC CapM (5 yr)			RAC Rehab (10 yr)								
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	9	0	10	3,915			9	4,270		10	3,915							
		3		Year of Action		0		9				18			27								
				Activity Description		RAC CapM (5 yr)		RAC CapM (5 yr)				RAC CapM (5 yr)			Reconst. (20 yr)								
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	9	0	9	4,270			9	4,270		20	1,167							
	10	1,2		Year of Action		0				10								35					
				Activity Description		RAC CapM (10 yr)				RAC Rehab (20 yr)								RAC CapM (10 yr)					
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	10	3,915			25	3,530							10	3,915				
		3		Year of Action		0				10								35					
				Activity Description		RAC CapM (10 yr)				RAC Rehab (20 yr)								RAC CapM (10 yr)					
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	10	3,915			25	3,530							10	3,915				
RAC w/ RAC-O	10	1,2																					
		3																					

Table F1-2 (3)

Rubberized Asphalt Concrete Pavement Maintenance & Rehabilitation Schedule

(Rehabilitation at Coastal Climate Region)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year		0		5	10		15		20		25		30		35	40	45	50	55
Rehabilitation																							
RAC	10	1,2,3		Year of Action		0			10		19				29								
				Activity Description		RAC Rehab (10 yr)			RAC CapM (5 yr)		RAC Rehab (10 yr)				RAC CapM (5 yr)								
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	10	3,915		9	4,270	10	3,915			9	4,270							
	20	1,2,3		Year of Action		0							25				34						
				Activity Description		RAC Rehab (20 yr)							RAC CapM (5 yr)				RAC Rehab (20 yr)						
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	25	3,530						9	4,270			25	3,530					
RAC w/ RAC-O	10	1,2,3																					
	20	1,2,3																					
	40	1,2,3																					

Table F2-1 (1)

Hot Mixed Asphalt Pavement Maintenance & Rehabilitation Schedule

(New Construction/Reconstruction at Inland Valley Climate Region)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year		0		5		10		15		20		25		30		35		40		45		50		55	
New Construction/Reconstruction																													
HMA	20	1,2	1	Year of Action		0						18		23				33		38				48		53			
				Activity Description		New Const./ Reconst. (20 yr)						CapM (5 yr)		Rehab (10 yr)				CapM (5 yr)		Rehab (10 yr)				CapM (5 yr)		Rehab (10 yr)			
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	18	1,252					5	1,096	10	2,675			5	1,096	10	2,675			5	$1,096	10	2,675		
			2	Year of Action		0						18		23								41		46					
				Activity Description		New Const./ Reconst. (20 yr)						CapM (5 yr)		Rehab (20 yr)								CapM (5 yr)		Rehab (20 yr)					
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	18	1,252					5	1,096	18	1,252							5	1,096	18	1,252				
		3		Year of Action		0						18				28				38				43					
				Activity Description		New Const./ Reconst. (20 yr)						CapM (5 yr)				CapM (5 yr)				CapM (5 yr)				Reconst. (20 yr)					
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	18	1,252					10	2,675			10	2,675			5	1,096			18	1,252				
HMA w/ OGFC	20	1,2	1	Year of Action		0								20				30						45				55	
				Activity Description		New Const./ Reconst. (20 yr)								CapM w/ OGFC (5 yr)				Rehab w/ OGFC (10 yr)						CapM w/ OGFC (5 yr)				Rehab w/ OGFC (10 yr)	
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	20	1,571							10	3,464			15	2,247					10	3,464			15	2,247
			2	Year of Action		0								20				30										54	
				Activity Description		New Const./ Reconst. (20 yr)								CapM w/ OGFC (5 yr)				Rehab w/ OGFC (20 yr)										CapM w/ OGFC (5 yr)	
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	20	1,571							10	3,464			24	2,726									10	3,464
		3		Year of Action		0								20				30				40				50			
				Activity Description		New Const./ Reconst. (20 yr)								CapM w/ OGFC (5 yr)				CapM w/ OGFC (5 yr)				CapM w/ OGFC (5 yr)				Reconst. (20 yr)			
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	20	1,571							10	3,464			10	3,464			10	3,464			20	1,571		
	40	1,2		Year of Action		0																40				50			
				Activity Description		New Const./ Reconst. (40 yr)																CapM w/ OGFC (5 yr)				Reconst. (20 yr)			
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	40	2,466															10	3,464			20	1,571		
		3		Year of Action		0																40				50			
				Activity Description		New Const./ Reconst.																CapM w/ OGFC (5 yr)				CapM w/ OGFC (5 yr)			
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	40	2,466															10	3,464			10	3,464		

Table F2-1 (2)

<u>Hot Mixed Asphalt Pavement Maintenance & Rehabilitation Schedule</u>

(CAPM at Inland Valley Climate Region)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year		0		5		10		15		20		25		30		35		40		45		50		55	
CapM																													
HMA	5	1,2		Year of Action		0		5				15		20															
				Activity Description		CapM (5 yr)		Rehab (10 yr)				CapM (5 yr)		Rehab (10 yr)															
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	5	1,096	10	2,675			5	1,096	10	2,675														
		3		Year of Action		0		5				15				20													
				Activity Description		CapM (5 yr)		CapM (5 yr)				CapM (5 yr)				CapM (5 yr)													
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	5	1,096	10	2,675			5	1,096			5	1,096												
	10	1,2		Year of Action		0				10						28						40							
				Activity Description		CapM (10 yr)				Rehab (20 yr)						CapM (10 yr)						Rehab (20 yr)							
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	10	2,675			18	1,252					12	2,312					18	1,252						
		3		Year of Action		0				10				20				30											
				Activity Description		CapM (10 yr)				CapM (10 yr)				CapM (10 yr)				CapM (10 yr)											
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	10	2,675			10	2,675			10	2,675			10	2,675										
HMA w/ OGFC	5	1,2		Year of Action		0				10						25													
				Activity Description		CapM w/ OGFC (5 yr)				Rehab w/ OGFC (10 yr)						CapM w/ OGFC (5 yr)													
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	10	3,464			15	2,247					10	3,464												
		3		Year of Action		0				10				20															
				Activity Description		CapM w/ OGFC (5 yr)				CapM w/ OGFC (5 yr)				CapM w/ OGFC (5 yr)															
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	10	3,464			10	3,464			10	3,464														
	10	1,2		Year of Action		0						15								35									
				Activity Description		CapM w/ OGFC (10 yr)						Rehab w/ OGFC (20 yr)								CapM w/ OGFC (10 yr)									
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	15	2,247					20	1,571							15	2,247								
		3		Year of Action		0						15																	
				Activity Description		CapM w/ OGFC (10 yr)						CapM w/ OGFC (10 yr)																	
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	15	2,247					15	2,247																

Table F2-1 (3)

Hot Mixed Asphalt Pavement Maintenance & Rehabilitation Schedule

(Rehabilitation at Inland Valley Climate Region)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year		0		5		10		15		20		25		30		35		40		45		50		55	
Rehabilitation																													
HMA	10	1,2,3		Year of Action		0				9		15				25				35									
				Activity Description		Rehab (10 yr)				CapM (5 yr)		Rehab (10 yr)				CapM (5 yr)				Rehab (10 yr)									
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	9	2,940			6	895	10	2,675			10	2,675			10	2,675								
	20	1,2,3		Year of Action		0						18		23								41				51			
				Activity Description		Rehab (20 yr)						CapM (5 yr)		Rehab (20 yr)								CapM (5 yr)				Rehab (20 yr)			
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	18	1,252					5	1,096	18	1,252							10	2,675			18	1,252		
HMA w/ OGFC	10	1,2,3		Year of Action		0						15				25						40							
				Activity Description		Rehab w/ OGFC (10 yr)						CapM w/ OGFC (5 yr)				Rehab w/ OGFC (10 yr)						CapM w/ OGFC (5 yr)							
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	15	2,247					10	3,464			15	2,247					10	3,464						
	20	1,2,3		Year of Action		0								20				30											
				Activity Description		Rehab w/ OGFC (20 yr)								CapM w/ OGFC (5 yr)				Rehab w/ OGFC (20 yr)											
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	20	1,571							10	3,464			24	2,726										
	40	1,2,3		Year of Action		0																40							
				Activity Description		Rehab w/ OGFC (40 yr)																CapM w/ OGFC (5 yr)							
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	40	3,350															10	3,464						

Table F2-2 (1)

<u>Rubberized Asphalt Concrete Pavement Maintenance & Rehabilitation Schedule</u>

(New Construction/Reconstruction at Inland Valley Climate Region)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year	0	5	10	15	20	25	30	35	40	45	50	55
New Construction/Reconstruction																
RAC	20	1,2	1	Year of Action	0					26		36		46		
				Activity Description	New Const./ Reconst. (20 yr)					RAC Rehab (10 yr)		RAC CapM (5 yr)		RAC Rehab (10 yr)		
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	26 / 3,491					10 / 3,915		10 / 3,915		10 / 3,915		
			2	Year of Action	0					26			42		52	
				Activity Description	New Const./ Reconst. (20 yr)					RAC Rehab (20 yr)			RAC CapM (5 yr)		RAC Rehab (20 yr)	
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	26 / 3,491					16 / 2,153			10 / 3,915		16 / 2,153	
		3		Year of Action	0					29		37	42	50	55	
				Activity Description	New Const./ Reconst. (20 yr)					RAC CapM (5 yr)		RAC CapM (5 yr)	RAC CapM (5 yr)	RAC CapM (5 yr)	Reconst. (20 yr)	
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	29 / 3,286					8 / 0		5 / 0	8 / 0	5 / 0	16 / 2,153	
RAC w/ RAC-O	20	1,2	1													
			2													
		3														
	40	1,2														
		3														

Table F2-2 (2)

Rubberized Asphalt Concrete Pavement Maintenance & Rehabilitation Schedule

(CAPM at Inland Valley Climate Region)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year	0	5	10	15	20	25	30	35	40	45	50	55
CapM																
RAC	5	1,2		Year of Action	0	8		18		28						
				Activity Description	RAC CapM (5 yr)	RAC Rehab (10 yr)		RAC CapM (5 yr)		RAC Rehab (10 yr)						
				Activity Service Life (years)	8	10		10		10						
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	0	3,915		3,915		3,915						
		3		Year of Action	0	8		18		25						
				Activity Description	RAC CapM (5 yr)	RAC CapM (5 yr)		RAC CapM (5 yr)		RAC CapM (5 yr)						
				Activity Service Life (years)	8	10		7		10						
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	0	3,915		0		3,915						
	10	1,2		Year of Action	0		10					38				
				Activity Description	RAC CapM (10 yr)		RAC Rehab (20 yr)					RAC Rehab (20 yr)				
				Activity Service Life (years)	10		28					28				
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,915		3,272					3,269				
		3		Year of Action	0		10		20		30					
				Activity Description	RAC CapM (10 yr)		RAC CapM (5 yr)		RAC CapM (10 yr)		RAC CapM (5 yr)					
				Activity Service Life (years)	10		10		10		10					
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,915		3,915		3,915		3,915					
RAC w/ RAC-O	10	1,2														
		3														

Table F2-2 (3)

Rubberized Asphalt Concrete Pavement Maintenance & Rehabilitation Schedule

(Rehabilitation at Inland Valley Climate Region)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year	0	5	10	15	20	25	30	35	40	45	50	55
Rehabilitation																
RAC	10	1,2,3		Year of Action	0		10	19		29						
				Activity Description	RAC Rehab (10 yr)		RAC CapM (5yr)	RAC Rehab (10yr)		CapM (5yr)						
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	10 / 3,915		9 / 4,270	10 / 3,915		9 / 4,270						
	20	1,2,3		Year of Action	0					25			41		50	
				Activity Description	RAC Rehab (20 yr)					RAC Rehab (20 yr)			AR Chip Seal CapM (5yr)		RAC Rehab (20 yr)	
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	25 / 3,572					16 / 2,153			9 / 4,270		16 / 2,153	
RAC w/ RAC-O	10	1,2,3														
	20	1,2,3														
	40	1,2,3														

Table F3-1 (1)

Hot Mixed Asphalt Pavement Maintenance & Rehabilitation Schedule

(New Construction/Reconstruction at Desert Climate Region)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year	0	5	10	15	20	25	30	35	40	45	50	55
New Construction/Reconstruction																
HMA	20	1,2	1	Year of Action	0			18	23		32	37		46	51	
				Activity Description	New Const./ Reconst. (20 yr)			CapM (5 yr)	Rehab (10 yr)		CapM (5 yr)	Rehab (10 yr)		CapM (5 yr)	Rehab (10 yr)	
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	18 / 2,188			5 / 1,096	9 / 2,940		5 / 1,096	9 / 2,940		5 / 1,096	9 / 2,940	
			2	Year of Action	0			18	23				41		51	
				Activity Description	New Const./ Reconst. (20 yr)			CapM (5 yr)	Rehab (20 yr)				CapM (5 yr)		Rehab (20 yr)	
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	18 / 2,188			5 / 1,096	18 / 2,188				10 / 2,675		18 / 2,188	
		3		Year of Action	0			18		28		38	43			
				Activity Description	New Const./ Reconst. (20 yr)			CapM (5 yr)		CapM (5 yr)		CapM (5 yr)	Reconstruct (20 yr)			
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	18 / 2,188			10 / 2,675		10 / 2,675		5 / 1,096	18 / 2,188			
HMA w/ OGFC	20	1,2	1	Year of Action	0				20	29			44		53	
				Activity Description	New Const./ Reconst. (20 yr)				CapM w/ OGFC (5 yr)	Rehab w/ OGFC (10 yr)			CapM w/ OGFC (5 yr)		Rehab w/ OGFC (10 yr)	
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	20 / 3,235				9 / 3,779	15 / 2,247			9 / 3,779		15 / 2,247	
			2	Year of Action	0				20	29					53	
				Activity Description	New Const./ Reconst. (20 yr)				CapM w/ OGFC (5 yr)	Rehab w/ OGFC (20 yr)					CapM w/ OGFC (5 yr)	
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	20 / 3,235				9 / 3,779	24 / 2,726					9 / 3,779	
		3		Year of Action	0				20	29		39		49		
				Activity Description	New Const./ Reconst. (20 yr)				CapM w/ OGFC (5 yr)	CapM w/ OGFC (5 yr)		CapM w/ OGFC (5 yr)		Reconstruct (20 yr)		
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	20 / 3,235				9 / 3,779	10 / 2,961		10 / 2,961		20 / 3,235		
	40	1,2		Year of Action	0								40		49	
				Activity Description	New Const./ Reconst. (40 yr)								CapM w/ OGFC (5 yr)		Rehab w/ OGFC (20 yr)	
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	40 / 4,010								9 / 3,779		24 / 2726	
		3		Year of Action	0								40		49	
				Activity Description	New Const./ Reconst.								CapM w/ OGFC (5 yr)		CapM w/ OGFC (5 yr)	
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	40 / 4,010								9 / 3,779		9 / 3,779	

Table F3-1 (2)

Hot Mixed Asphalt Pavement Maintenance & Rehabilitation Schedule

(CAPM at Desert Climate Region)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year	0	5	10	15	20	25	30	35	40	45	50	55
CapM																
HMA	5	1,2		Year of Action	0	5	14	19								
				Activity Description	CapM (5 yr)	Rehab (10 yr)	CapM (5 yr)	Rehab (10 yr)								
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	5 / 1,096	9 / 2,940	5 / 1,096	9 / 2,940								
		3		Year of Action	0	5	10	15	20							
				Activity Description	CapM (5 yr)	CapM (5 yr)	CapM (5 yr)	CapM (5 yr)	CapM (5 yr)							
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	5 / 1,096	5 / 1,096	5 / 1,096	5 / 1,096	5 / 1,096							
	10	1,2		Year of Action	0		10			28		38				
				Activity Description	CapM (10 yr)		Rehab (20 yr)			CapM (10 yr)		Rehab (20 yr)				
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	10 / 2,675		18 / 1,406			10 / 2,675		18 / 1,406				
		3		Year of Action	0		10		20		30					
				Activity Description	CapM (10 yr)		CapM (10 yr)		CapM (10 yr)		CapM (10 yr)					
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	10 / 2,675		10 / 2,675		10 / 2,675		10 / 2,675					
HMA w/ OGFC	5	1,2		Year of Action	0		10		23							
				Activity Description	CapM w/ OGFC (5 yr)		Rehab w/ OGFC (10 yr)		Rehab w/ OGFC (10 yr)							
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	10 / 3,464		13 / 2,602		13 / 2,602							
		3		Year of Action	0		10		20							
				Activity Description	CapM w/ OGFC (5 yr)		CapM w/ OGFC (5 yr)		CapM w/ OGFC (5 yr)							
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	10 / 3,464		10 / 3,464		10 / 3,464							
	10	1,2		Year of Action	0		14					39				
				Activity Description	CapM w/ OGFC (10 yr)		Rehab w/ OGFC (20 yr)					CapM w/ OGFC (10 yr)				
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	14 / 2,459		25 / 2,767					14 / 2,459				
		3		Year of Action	0		14			28						
				Activity Description	CapM w/ OGFC (10 yr)		CapM w/ OGFC (10 yr)			CapM w/ OGFC (10 yr)						
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	14 / 2,459		14 / 2,459			14 / 2,459						

Table F3-1 (3)

Hot Mixed Asphalt Pavement Maintenance & Rehabilitation Schedule

(Rehabilitation at Desert Climate Region)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year		0		5		10		15		20		25		30		35		40		45		50		55	
Rehabilitation																													
HMA	10	1,2,3		Year of Action		0				10		15				25		30											
				Activity Description		Rehab (10 yr)				CapM (5 yr)		Rehab (10 yr)				CapM (5 yr)		Rehab (10 yr)											
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	10	2,675			5	1,096	10	2,675			5	1,096	10	2,675										
	20	1,2,3		Year of Action		0						18		23								41				51			
				Activity Description		Rehab (20 yr)						CapM (5 yr)		Rehab (20 yr)								CapM (5 yr)				Rehab (20 yr)			
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	18	2,188					5	1,096	18	2,188							10	2,675			18	2,188		
HMA w/ OGFC	10	1,2,3		Year of Action		0				13				22				32											
				Activity Description		Rehab w/ OGFC (10 yr)				CapM w/ OGFC (5 yr)				Rehab w/ OGFC (10 yr)				CapM w/ OGFC (5 yr)											
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	13	2,602			9	3,779			10	3,464			9	3,779										
	20	1,2,3		Year of Action		0						18				27								45		54			
				Activity Description		Rehab w/ OGFC (20 yr)						CapM w/ OGFC (5 yr)				Rehab w/ OGFC (20 yr)								CapM w/ OGFC (5 yr)		Rehab w/ OGFC (20 yr)			
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	18	3,674					9	3,779			18	$3,674							9	3,779	18	$3,674		
	40	1,2,3		Year of Action		0																40		49					
				Activity Description		Rehab w/ OGFC (40 yr)																CapM w/ OGFC (5 yr)		Rehab w/ OGFC (20 yr)					
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	40	4,010															9	3,779	18	$3,674				

Table F3-2 (1)
Rubberized Asphalt Concrete Pavement Maintenance & Rehabilitation Schedule
(New Construction/Reconstruction at Desert Climate Region)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year		0		5	10	15	20	25		30	35		40		45		50		55
New Construction/Reconstruction																							
RAC	20	1,2	1	Year of Action		0						26			36				46				
				Activity Description		New Const./ Reconst. (20 yr)						RAC Rehab (10 yr)			RAC CapM (5 yr)				RAC Rehab (10 yr)				
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	26	3,491					10	3,915		10	3,915			10	3,915			
			2	Year of Action		0						26					42				52		
				Activity Description		New Const./ Reconst. (20 yr)						RAC Rehab (20 yr)					RAC CapM (5 yr)				RAC Rehab (20 yr)		
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	26	3,491					16	2,153				10	3,915			16	2,153	
		3		Year of Action		0						29			37		42		50		55		
				Activity Description		New Const./ Reconst. (20 yr)						RAC CapM (5 yr)			RAC CapM (5 yr)		RAC CapM (5 yr)		RAC CapM (5 yr)		New Const./ Reconst. (20		
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	29	3,286					8	0		5	0	8	0	5	0	16	2,153	
RAC w/ RAC-O	20	1,2	1																				
			2																				
		3																					
	40	1,2																					
		3																					

Table F3-2 (2)

<u>Rubberized Asphalt Concrete Pavement Maintenance & Rehabilitation Schedule</u>

(CAPM at Desert Climate Region)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year	0	5	10	15	20	25	30	35	40	45	50	55
CapM																
RAC	5	1,2		Year of Action	0	8				26						
				Activity Description	RAC CapM (5 yr)	RAC Rehab (10 yr)				RAC Rehab (10 yr)						
				Activity Service Life (years)	8	18				18						
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	0	5,716				5,716						
		3		Year of Action	0			18								
				Activity Description	RAC CapM (5 yr)			RAC CapM (5 yr)								
				Activity Service Life (years)	18			18								
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	6,033			6,033								
	10	1,2		Year of Action	0		10					38				
				Activity Description	RAC CapM (10 yr)		RAC Rehab (20 yr)					RAC Rehab (20 yr)				
				Activity Service Life (years)	10		28					28				
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,915		3,272					3,272				
		3		Year of Action	0				20							
				Activity Description	RAC CapM (10 yr)				RAC CapM (10 yr)							
				Activity Service Life (years)	20				20							
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	5,196				5,196							
RAC w/ RAC-O	10	1,2														
		3														

Table F3-2 (3)
Rubberized Asphalt Concrete Pavement Maintenance & Rehabilitation Schedule
(Rehabilitation at Desert Climate Region)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year		0		5	10	15		20		25	30	35		40	45		50	55
Rehabilitation																						
RAC	10	1,2,3		Year of Action		0				18						36						
				Activity Description		RAC Rehab (10 yr)				RAC Rehab (10 yr)						RAC Rehab (10 yr)						
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	18	5,645			18	5,645					18	5,645					
	20	1,2,3		Year of Action		0						24							48			
				Activity Description		RAC Rehab (20 yr)						RAC Rehab (20 yr)							RAC Rehab (20 yr)			
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	24	3,704					24	3,704						24	3,704		
RAC w/ RAC-O	10	1,2,3																				
	20	1,2,3																				
	40	1,2,3																				

Table F4-1 (1)

Hot Mixed Asphalt Pavement Maintenance & Rehabilitation Schedule

(New Construction/Reconstruction at Low Mountain and South Mountain Climate Regions)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year		0		5		10		15		20		25		30		35		40		45		50		55	
New Construction/Reconstruction																													
HMA	20	1,2	1	Year of Action		0						19		24				34		39				49		54			
				Activity Description		New Const./ Reconst. (20 yr)						CapM (5 yr)		Rehab (10 yr)				CapM (5 yr)		Rehab (10 yr)				CapM (5 yr)		Rehab (10 yr)			
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	19	1,552					5	3,112	10	1,579			5	3,112	10	1,579			5	3,112	10	1,579		
			2	Year of Action		0						19		24								43		48					
				Activity Description		New Const./ Reconst. (20 yr)						CapM (5 yr)		Rehab (20 yr)								CapM (5 yr)		Rehab (20 yr)					
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	19	1,552					5	3,112	19	1,552							5	3,112	19	1,552				
		3		Year of Action		0						19						31				43						55	
				Activity Description		New Const./ Reconst. (20 yr)						CapM (5 yr)						CapM (5 yr)				CapM (5 yr)						CapM (5 yr)	
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	19	1,552					12	6,122					12	6,122			12	6,122					12	6,122
HMA w/ OGFC	20	1,2	1	Year of Action		0								23		29				39		44				54			
				Activity Description		New Const./ Reconst. (20 yr)								CapM w/ OGFC (5 yr)		Rehab w/ OGFC (10 yr)				CapM w/ OGFC (5 yr)		Rehab (10 yr)				Rehab w/ OGAC (20 yr)			
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	23	4,141							6	0	10	3,464			5	0	10	3,464			23	4,141		
			2	Year of Action		0								23		29										52			
				Activity Description		New Const./ Reconst. (20 yr)								CapM w/ OGFC (5 yr)		Rehab w/ OGFC (20 yr)										CapM w/ OGFC (5 yr)			
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	23	4,141							6	0	23	4,141									6	0		
		3		Year of Action		0								20		29				38				47					
				Activity Description		New Const./ Reconst. (20 yr)								CapM w/ OGFC (5 yr)		CapM w/ OGFC (5 yr)				CapM w/ OGFC (5 yr)				Reconstruct (20 yr)					
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	20	3,235							9	3,779	9	3,779			9	3,779			20	3,235				
	40	1,2		Year of Action		0																40		46					
				Activity Description		New Const./ Reconst. (40 yr)																CapM w/ OGFC (5 yr)		Rehab w/ OGFC (20 yr)					
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	40	4,117															6	0	23	4,141				
		3		Year of Action		0																40		49					
				Activity Description		New Const./ Reconst.																CapM w/ OGFC (5 yr)		CapM w/ OGFC (5 yr)					
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	40	4,117															9	3,779	9	3,779				

Table F4-1 (2)

Hot Mixed Asphalt Pavement Maintenance & Rehabilitation Schedule

(CAPM at Low Mountain and South Mountain Climate Regions)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year	0	5	10	15	20	25	30	35	40	45	50	55
CapM																
HMA	5	1,2		Year of Action	0	5		15	20							
				Activity Description	CapM (5 yr)	Rehab (10 yr)		CapM (5 yr)	Rehab (10 yr)							
				Activity Service Life (years)	5	10		5	10							
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,112	7,187		3,112	7,187							
		3		Year of Action	0		12		24							
				Activity Description	CapM (5 yr)		CapM (5 yr)		CapM (5 yr)							
				Activity Service Life (years)	12		12		12							
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	6,122		6,122		6,122							
	10	1,2		Year of Action	0		10				30					
				Activity Description	CapM (10 yr)		Rehab (20 yr)				CapM (10 yr)					
				Activity Service Life (years)	10		20				10					
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	1,579		1,412				1,579					
		3		Year of Action	0			15			30					
				Activity Description	CapM (10 yr)			CapM (10 yr)			CapM (10 yr)					
				Activity Service Life (years)	15			15			15					
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	2,099			2,099			2,099					
HMA w/ OGFC	5	1,2		Year of Action	0		10		23							
				Activity Description	CapM w/ OGFC (5 yr)		Rehab w/ OGFC (10 yr)		CapM w/ OGFC (5 yr)							
				Activity Service Life (years)	10		13		10							
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,464		2,602		3,464							
		3		Year of Action	0		11		22							
				Activity Description	CapM w/ OGFC (5 yr)		CapM w/ OGFC (5 yr)		CapM w/ OGFC (5 yr)							
				Activity Service Life (years)	11		11		11							
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	6,329		6,329		6,329							
	10	1,2		Year of Action	0		13					36				
				Activity Description	CapM w/ OGFC (10 yr)		Rehab w/ OGFC (20 yr)					CapM w/ OGFC (10 yr)				
				Activity Service Life (years)	13		23					13				
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	2,623		4,480					2,623				
		3		Year of Action	0			15			30					
				Activity Description	CapM w/ OGFC (10 yr)			CapM w/ OGFC (10 yr)			CapM w/ OGFC (10 yr)					
				Activity Service Life (years)	15			15			15					
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	6,882			6,882			6,882					

Table F4-1 (3)

Hot Mixed Asphalt Pavement Maintenance & Rehabilitation Schedule

(Rehabilitation at Low Mountain and South Mountain Climate Regions)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year		0		5		10		15		20		25		30		35		40		45		50		55	
Rehabilitation																													
HMA	10	1,2,3		Year of Action		0				10		15				25		30											
				Activity Description		Rehab (10 yr)				CapM (5 yr)		Rehab (10 yr)				CapM (5 yr)		Rehab (10 yr)											
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	10	1,579			5	3,112	10	1,579			5	3,112	10	1,579										
	20	1,2,3		Year of Action		0						19		24								43		48					
				Activity Description		Rehab (20 yr)						CapM (5 yr)		Rehab (20 yr)								CapM (5 yr)		Rehab (20 yr)					
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	19	1,552					5	3,112	19	1,552							5	3,112	19	1,552				
HMA w/ OGFC	10	1,2,3		Year of Action		0				12		18						30		36									
				Activity Description		Rehab w/ OGFC (10 yr)				CapM w/ OGFC (5 yr)		Rehab w/ OGFC (10 yr)						CapM w/ OGFC (5 yr)		Rehab w/ OGFC (10 yr)									
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	12	5,787			6	0	12	5,787					6	0	12	5,787								
	20	1,2,3		Year of Action		0								23		29										52			
				Activity Description		Rehab w/ OGFC (20 yr)								CapM w/ OGFC (5 yr)		Rehab w/ OGFC (20 yr)										CapM w/ OGFC (5 yr)			
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	23	4,141							6	0	23	4,141									6	0		
	40	1,2,3		Year of Action		0																40		46					
				Activity Description		Rehab w/ OGFC (40 yr)																CapM w/ OGFC (5 yr)		Rehab w/ OGFC (20 yr)					
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	40	4,117															6	0	23	4,141				

Table F4-2 (1)

Rubberized Asphalt Concrete Pavement Maintenance & Rehabilitation Schedule

(New Construction/Reconstruction at Low Mountain and South Mountain Climate Regions)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year	0	5	10	15	20	25	30	35	40	45	50	55
New Construction/Reconstruction																
RAC	20	1,2	1	Year of Action	0					26		36		46		
				Activity Description	New Const./ Reconst. (20 yr)					RAC Rehab (10 yr)		RAC CapM (5 yr)		RAC Rehab (10 yr)		
				Activity Service Life (years)	26					10		10		10		
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,491					3,915		3,915		3,915		
			2	Year of Action	0					26			42		52	
				Activity Description	New Const./ Reconst. (20 yr)					RAC Rehab (20 yr)			RAC CapM (5 yr)		RAC Rehab (20 yr)	
				Activity Service Life (years)	26					16			10		16	
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,491					2,153			3,915		2,153	
		3		Year of Action	0					29		37	42	50	55	
				Activity Description	New Const./ Reconst. (20 yr)					RAC CapM (5 yr)		RAC CapM (5 yr)	RAC CapM (5 yr)	RAC CapM (5 yr)	New Const./ Reconst. (20	
				Activity Service Life (years)	29					8		5	8	5	16	
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,286					0		0	0	0	2,153	
RAC w/ RAC-O	20	1,2	1													
			2													
		3														
	40	1,2														
		3														

Table F4-2 (2)
Rubberized Asphalt Concrete Pavement Maintenance & Rehabilitation Schedule
(CAPM at Low Mountain and South Mountain Climate Regions)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year	0	5	10	15	20	25	30	35	40	45	50	55
CapM																
RAC	5	1,2		Year of Action	0	8				26						
				Activity Description	RAC CapM (5 yr)	RAC Rehab (10 yr)				RAC Rehab (10 yr)						
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	8 / 0	18 / 5,716				18 / 5,716						
		3		Year of Action	0			18								
				Activity Description	RAC CapM (5 yr)			RAC CapM (5 yr)								
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	18 / 6,033			18 / 6,033								
	10	1,2		Year of Action	0		10					38				
				Activity Description	RAC CapM (10 yr)		RAC Rehab (20 yr)					RAC Rehab (20 yr)				
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	10 / 3,915		28 / 3,272					28 / 3,272				
		3		Year of Action	0				20							
				Activity Description	RAC CapM (10 yr)				RAC CapM (10 yr)							
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	20 / 5,196				20 / 5,196							
RAC w/ RAC-O	10	1,2														
		3														

Table F4-2 (3)

Rubberized Asphalt Concrete Pavement Maintenance & Rehabilitation Schedule

(Rehabilitation at Low Mountain and South Mountain Climate Regions)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year		0		5	10	15		20		25	30	35		40	45		50	55
Rehabilitation																						
RAC	10	1,2,3		Year of Action		0				18						36						
				Activity Description		RAC Rehab (10 yr)				RAC Rehab (10 yr)						RAC Rehab (10 yr)						
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	18	5,645			18	5,645					18	5,645					
	20	1,2,3		Year of Action		0						24							48			
				Activity Description		RAC Rehab (20 yr)						RAC Rehab (20 yr)							RAC Rehab (20 yr)			
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	24	3,704					24	3,704						24	3,704		
RAC w/ RAC-O	10	1,2,3																				
	20	1,2,3																				
	40	1,2,3																				

Table F5-1 (1)
Hot Mixed Asphalt Pavement Maintenance & Rehabilitation Schedule
(New Construction/Reconstruction at High Mountain and High Desert Climate Regions)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year	0	5	10	15	20	25	30	35	40	45	50	55
New Construction/Reconstruction																
HMA	20	1,2	1	Year of Action	0			19	24		34	39		49	54	
				Activity Description	New Const./ Reconst. (20 yr)			CapM (5 yr)	Rehab (10 yr)		CapM (5 yr)	Rehab (10 yr)		CapM (5 yr)	Rehab (10 yr)	
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	19 / 1,552			5 / 3,112	10 / 1,579		5 / 3,112	10 / 1,579		5 / 3,112	10 / 1,579	
			2	Year of Action	0			19	24				43	48		
				Activity Description	New Const./ Reconst. (20 yr)			CapM (5 yr)	Rehab (20 yr)				CapM (5 yr)	Rehab (20 yr)		
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	19 / 1,552			5 / 3,112	19 / 1,552				5 / 3,112	19 / 1,552		
		3		Year of Action	0			19			31		43			55
				Activity Description	New Const./ Reconst. (20 yr)			CapM (5 yr)			CapM (5 yr)		CapM (5 yr)			CapM (5 yr)
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	19 / 1,552			12 / 6,146			12 / 6,146		12 / 6,146			12 / 6,146

Table F5-1 (2)
Hot Mixed Asphalt Pavement Maintenance & Rehabilitation Schedule
(CAPM at High Mountain and High Desert Climate Regions)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year	0	5	10	15	20	25	30	35	40	45	50	55
CapM																
HMA	5	1,2		Year of Action	0	5		15	20							
				Activity Description	CapM (5 yr)	Rehab (10 yr)		CapM (5 yr)	Rehab (10 yr)							
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	5 / 3,112	10 / 7,187		5 / 3,112	10 / 7,187							
		3		Year of Action	0		12		24							
				Activity Description	CapM (5 yr)		CapM(5 yr)		CapM(5 yr)							
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	12 / 6,122		12 / 6,122		12 / 6,122							
	10	1,2		Year of Action	0		10				30					
				Activity Description	CapM (10 yr)		Rehab (20 yr)				CapM (10 yr)					
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	10 / 1,579		20 / 1,412				10 / 1,579					
		3		Year of Action	0			15			30					
				Activity Description	CapM (10 yr)			CapM (10 yr)			CapM (10 yr)					
				Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	15 / 2,099			15 / 2,099			15 / 2,099					

Table F5-1 (3)

Hot Mixed Asphalt Pavement Maintenance & Rehabilitation Schedule

(Rehabilitation at High Mountain and High Desert Climate Regions)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year		0		5		10		15		20		25		30		35		40		45		50		55	
Rehabilitation																													
HMA	10	1,2,3		Year of Action		0				10		15				25		30											
				Activity Description		Rehab (10 yr)				CapM (5 yr)		Rehab (10 yr)				CapM (5 yr)		Rehab (10 yr)											
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	10	1,579			5	3,112	10	1,579			5	3,112	10	1,579										
	20	1,2,3		Year of Action		0						19		24								43		48					
				Activity Description		Rehab (20 yr)						CapM (5 yr)		Rehab (20 yr)								CapM (5 yr)		Rehab (20 yr)					
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	19	1,552					5	3,112	19	1,552							5	3,112	19	1,552				

Table F5-2 (1)

Rubberized Asphalt Concrete Pavement Maintenance & Rehabilitation Schedule

(New Construction/Reconstruction at High Mountain and High Desert Climate Regions)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year		0		5	10	15	20	25		30	35		40		45		50		55
New Construction/Reconstruction																							
RAC	20	1,2	1	Year of Action		0						26			36				46				
				Activity Description		New Const./ Reconst. (20 yr)						RAC Rehab (10 yr)			RAC CapM (5 yr)				RAC Rehab (10 yr)				
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	26	3,491					10	3,915		10	3,915			10	3,915			
			2	Year of Action		0						26					42				52		
				Activity Description		New Const./ Reconst. (20 yr)						RAC Rehab (20 yr)					RAC CapM (5 yr)				RAC Rehab (20 yr)		
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	26	3,491					16	2,153				10	3,915			16	2,153	
		3		Year of Action		0						29			37		42		50		55		
				Activity Description		New Const./ Reconst. (20 yr)						RAC CapM (5 yr)			RAC CapM (5 yr)		RAC CapM (5 yr)		RAC CapM (5 yr)		Reconst. (20 yr)		
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	29	3,286					8	0		5	0	8	0	5	0	16	2,153	
RAC w/ RAC-O	20	1,2	1																				
			2																				
		3																					
	40	1,2																					
		3																					

Table F5-2 (2)
Rubberized Asphalt Concrete Pavement Maintenance & Rehabilitation Schedule
(CAPM at High Mountain and High Desert Climate Regions)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year		0	5	10	15	20	25	30	35	40	45	50	55
CapM																	
RAC	5	1,2		Year of Action		0	8		18		26						
				Activity Description		RAC CapM (5 yr)	RAC Rehab (10 yr)		RAC CapM (5 yr)		RAC Rehab (10 yr)						
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	8 5,101	10 3,915		8 5,101		10 3,915						
		3		Year of Action		0	8		18		25						
				Activity Description		RAC CapM (5 yr)	RAC CapM (5 yr)		RAC CapM (5 yr)		RAC CapM (5 yr)						
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	8 0	10 3,915		7 0		10 3,915						
	10	1,2		Year of Action		0		10			26		38				
				Activity Description		RAC CapM (10 yr)		RAC Rehab (20 yr)			RAC CapM (5 yr)		RAC Rehab (20 yr)				
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	10 3,915		16 2,153			12 3,128		16 2,153				
		3		Year of Action		0		10		20		30					
				Activity Description		RAC CapM (10 yr)		RAC CapM (5 yr)		RAC CapM (10 yr)		RAC CapM (5 yr)					
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	10 3,915		10 3,915		10 3,915		10 3,915					
RAC w/ RAC-O	10	1,2															
		3															

Table F5-2 (3)

Rubberized Asphalt Concrete Pavement Maintenance & Rehabilitation Schedule

(Rehabilitation at High Mountain and High Desert Climate Regions)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year		0		5	10		15		20		25		30	35		40	45		50	55
Rehabilitation																								
RAC	10	1,2,3		Year of Action		0			10		18				28			36						
				Activity Description		RAC Rehab (10 yr)			RAC CapM (5 yr)		RAC Rehab (10 yr)				RAC CapM (5 yr)			RAC Rehab (10 yr)						
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	10	3,915		8	4,905	10	3,915			8	4,905		10	3,915					
	20	1,2,3		Year of Action		0							24								48			
				Activity Description		RAC Rehab (20 yr)							RAC Rehab (20 yr)								RAC Rehab (20 yr)			
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	24	3,704						24	3,704							16	2,153		
RAC w/ RAC-O	10	1,2,3																						
	20	1,2,3																						
	40	1,2,3																						

Table R1 (1)

Rigid Pavement Maintenance & Rehabilitation Schedule

(New Construction/Reconstruction at Coastal, Inland Valley, Dessert, and Low Mountain & South Mountain Climate Regions)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year		0		5	10	15	20		25	30		35		40		45	50		55	
New Construction/Reconstruction																								
New Lane	20	1,2,3		Year of Action		0					20			30		35		40						
				Activity Description		New Const./ Reconst. (20 yr)					10-yr CapM (Conc Pvmt Rehab #3*)			5-yr CapM (Conc Pvmt Rehab #2*)		5-yr CapM (Conc Pvmt Rehab #1*)		Roadway Rehab*		*Follow the strategy listed in this table for the Roadway Rehabilitation Option selected.*				
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	20	1,011				10	2,229		5	4,393	5	4,393							
	40	1,2,3		Year of Action		0												40			50		55	
				Activity Description		New Const./ Reconst.												10-yr CapM (Conc Pvmt Rehab #3*)			5-yr CapM (Conc Pvmt Rehab #2*)		5-yr CapM (Conc Pvmt Rehab #1*)	
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	40	731											10	2,229		5	4,393	5	4,393

Notes:

(1) Conc Pvmt Rehab C involves pavement grinding, minor slab replacement, spall repair, & joint seal repair. It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is 2% or less.

(2) Conc Pvmt Rehab B involves pavement grinding, moderate slab replacement, spall repair, & joint seal repair. It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is between 2 and 5%.

(3) Conc Pvmt Rehab A involves pavement grinding, significant slab replacement, spall repair, & joint seal repair. It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is greater than or equal to 5% and less than or equal to 7%. For greater than 7%, the project should be scoped and analyzed as a roadway rehabilitation project.

(4) Select the roadway rehabilitation option found in Table R1 (3) that would best represent how the project will be rehabilitated in the future.

Table R1 (2)

Rigid Pavement Maintenance & Rehabilitation Schedule

(CAPM at Coastal, Inland Valley, Dessert, and Low Mountain & South Mountain Climate Regions)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year		0		5		10		15		20		25	30	35	40	45	50	55
CapM																						
Conc Pvmt Rehab #1*	5	1,2,3		Year of Action		0		5		Follow the strategy listed in this table for the Roadway Rehabilitation Option selected.												
				Activity Description		5-yr CapM (Conc Pvmt Rehab #1*)		Roadway Rehab*														
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	5	4,393															
Conc Pvmt Rehab #2*	5	1,2,3		Year of Action		0		5		10		Follow the strategy listed in this table for the Roadway Rehabilitation Option selected.										
				Activity Description		5-yr CapM (Conc Pvmt Rehab #2*)		5-yr CapM (Conc Pvmt Rehab #1*)		Roadway Rehab*												
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	5	4,393	5	4,393													
Conc Pvmt Rehab #3*	10	1,2,3		Year of Action		0				10		15		20		Follow the strategy listed in this table for the Roadway Rehabilitation Option selected.						
				Activity Description		10-yr CapM (Conc Pvmt Rehab #3*)				5-yr CapM (Conc Pvmt Rehab #2*)		5-yr CapM (Conc Pvmt Rehab #1*)		Roadway Rehab*								
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	10	2,229			5	4,393	5	4,393									

Notes:

(1) Conc Pvmt Rehab A involves pavement grinding, significant slab replacement, spall repair, & joint seal repair. It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is greater than or equal to 5% and less than or equal to 7%. For greater than 7%, the project should be scoped and analyzed as a roadway rehabilitation project.

(2) Select the roadway rehabilitation option found in Table R1 (3) that would best represent how the project will be rehabilitated in the future.

(3) Conc Pvmt Rehab B involves pavement grinding, moderate slab replacement, spall repair, & joint seal repair. It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is between 2 and 5%.

(4) Conc Pvmt Rehab C involves pavement grinding, minor slab replacement, spall repair, & joint seal repair. It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is 2% or less.

Table R1 (3)

Rigid Pavement Maintenance & Rehabilitation Schedule

(Rehabilitation at Coastal, Inland Valley, Dessert, and Low Mountain & South Mountain Climate Regions)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year	0	5	10	15	20	25	30	35	40	45	50	55
Rehabilitation																
Lane Replacement	20	1,2,3		Year of Action	0				20		30	35	40			
				Activity Description	20-yr Rehab (Lane Replacement)				10-yr CapM (Conc Pvmt Rehab #3*)		5-yr CapM (Conc Pvmt Rehab #2*)	5-yr CapM (Conc Pvmt Rehab #1*)	Roadway Rehab*	Follow the strategy listed in this table for the Roadway Rehabilitation Option selected.		
				Activity Service Life (years)	20				10		5	5				
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	1,011				2,229		4,393	4,393				
Lane Replacement	40	1,2,3		Year of Action	0								40		50	55
				Activity Description	40-yr Rehab (Lane Replacement)								10-yr CapM (Conc Pvmt Rehab #3*)		5-yr CapM (Conc Pvmt Rehab #2*)	5-yr CapM (Conc Pvmt Rehab #1*)
				Activity Service Life (years)	40								10		5	5
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	731								2,229		4,393	4,393
Rigid Crack, Seat, w/ 0.45' AC Overlay	20	1,2,3		Year of Action	0			18	23	28	33		42	49		
				Activity Description	20-yr Rehab (CSOL)			5-yr CapM (0.10' HMA Overlay)	5-yr CapM (0.15' HMA Overlay +2% Digout)	5-yr CapM (0.10' HMA Overlay)	10-yr Rehab (0.25' HMA Overlay +5% Digout)		5-yr CapM (0.15' HMA Overlay +2% Digout)	Reconst		
				Activity Service Life (years)	18			5	5	5	9		7			
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	1,321			0	0	0	631		813			
Rigid Crack, Seat, w/ 0.35' AC Overlay	10	1,2,3		Year of Action	0	9	14	19	24		33		40			
				Activity Description	10-yr Rehab (CSOL)	5-yr CapM (0.10' HMA Overlay)	5-yr CapM (0.15' HMA Overlay +2% Digout)	5-yr CapM (0.10' HMA Overlay)	10-yr Rehab (0.25' HMA Overlay +5% Digout)		5-yr CapM (0.15' HMA Overlay +2% Digout)		Reconst			
				Activity Service Life (years)	9	5	5	5	9		7					
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	0	0	0	0	631		813					

Notes:

(1) Conc Pvmt Rehab C involves pavement grinding, minor slab replacement, spall repair, & joint seal repair. It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is 2% or less.

(2) Conc Pvmt Rehab B involves pavement grinding, moderate slab replacement, spall repair, & joint seal repair. It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is between 2 and 5%.

(3) Conc Pvmt Rehab A involves pavement grinding, significant slab replacement, spall repair, & joint seal repair. It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is greater than or equal to 5% and less than or equal to 7%. For greater than 7%, the project should be scoped and analyzed as a roadway rehabilitation project.

(4) Select the roadway rehabilitation option found in this table that would best represent how the project will be rehabilitated in the future.

Table R2 (1)

Rigid Pavement Maintenance & Rehabilitation Schedule

(New Construction/Reconstruction at High Mountain & High Desert Climate Region)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year	0	5	10	15	20	25	30	35	40	45	50	55
New Construction/Reconstruction																
New Lane	20	1,2,3		Year of Action	0				20		30	35	40			
				Activity Description	New Const./ Reconst. (20 yr)				10-yr CapM (Conc Pvmt Rehab #3*)		5-yr CapM (Conc Pvmt Rehab #2*)	5-yr CapM (Conc Pvmt Rehab #1*)	Roadway Rehab*	*Follow the strategy listed in this table for the Roadway Rehabilitation Option selected.*		
				Activity Service Life (years)	20				10		5	5				
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	2,209				2,229		4,393	4,393				
	40	1,2,3		Year of Action	0								40		50	55
				Activity Description	New Const./ Reconst.								10-yr CapM (Conc Pvmt Rehab #3*)		5-yr CapM (Conc Pvmt Rehab #2*)	5-yr CapM (Conc Pvmt Rehab #1*)
				Activity Service Life (years)	40								10		5	5
				Annual Maint. Cost ($/lane-mile) over Activity Service Life	2,540								2,229		4,393	4,393

Notes:

(1) Conc Pvmt Rehab C involves pavement grinding, minor slab replacement, spall repair, & joint seal repair. It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is 2% or less.

(2) Conc Pvmt Rehab B involves pavement grinding, moderate slab replacement, spall repair, & joint seal repair. It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is between 2 and 5%.

(3) Conc Pvmt Rehab A involves pavement grinding, significant slab replacement, spall repair, & joint seal repair. It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is greater than or equal to 5% and less than or equal to 7%. For greater than 7%, the project should be scoped and analyzed as a roadway rehabilitation project.

(4) Select the roadway rehabilitation option found in Table R1 (3) that would best represent how the project will be rehabilitated in the future.

Table R2 (2)

Rigid Pavement Maintenance & Rehabilitation Schedule

(CAPM at High Mountain & High Desert Climate Region)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year		0		5		10		15		20		25	30	35	40	45	50	55
CapM																						
Conc Pvmt Rehab #1*	5	1,2,3		Year of Action		0		5		Follow the strategy listed in this table for the Roadway Rehabilitation Option selected.												
				Activity Description		5-yr CapM (Conc Pvmt Rehab #1*)		Roadway Rehab*														
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	5	4,393															
Conc Pvmt Rehab #2*	5	1,2,3		Year of Action		0		5		10		Follow the strategy listed in this table for the Roadway Rehabilitation Option selected.										
				Activity Description		5-yr CapM (Conc Pvmt Rehab #2*)		5-yr CapM (Conc Pvmt Rehab #1*)		Roadway Rehab*												
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	5	4,393	5	4,393													
Conc Pvmt Rehab #3*	10	1,2,3		Year of Action		0				10		15		20		Follow the strategy listed in this table for the Roadway Rehabilitation Option selected.						
				Activity Description		10-yr CapM (Conc Pvmt Rehab #3*)				5-yr CapM (Conc Pvmt Rehab #2*)		5-yr CapM (Conc Pvmt Rehab #1*)		Roadway Rehab*								
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	10	2,229			5	4,393	5	4,393									

Notes:

(1) Conc Pvmt Rehab C involves pavement grinding, minor slab replacement, spall repair, & joint seal repair. It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is 2% or less.

(2) Conc Pvmt Rehab B involves pavement grinding, moderate slab replacement, spall repair, & joint seal repair. It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is between 2 and 5%.

(3) Conc Pvmt Rehab A involves pavement grinding, significant slab replacement, spall repair, & joint seal repair. It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is greater than or equal to 5% and less than or equal to 7%. For greater than 7%, the project should be scoped and analyzed as a roadway rehabilitation project.

(4) Select the roadway rehabilitation option found in this table that would best represent how the project will be rehabilitated in the future.

Table R2 (3)

Rigid Pavement Maintenance & Rehabilitation Schedule

(Rehabilitation at High Mountain & High Desert Climate Region)

Final Surface Type	Pvmt Design Life	Maint. Service Level	Option	Year		0		5		10		15		20		25		30		35		40		45		50		55	
Rehabilitation																													
Lane Replacement	20	1,2,3		Year of Action		0								20				30		35		40		Follow the strategy listed in this table for the Roadway Rehabilitation Option selected.					
				Activity Description		20-yr Rehab (Lane Replacement)								10-yr CapM (Conc Pvmt Rehab #3*)				5-yr CapM (Conc Pvmt Rehab #2*)		5-yr CapM (Conc Pvmt Rehab #1*)		Roadway Rehab*							
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	20	2,209							10	2,229			5	4,393	5	4,393								
Lane Replacement	40	1,2,3		Year of Action		0																40				50		55	
				Activity Description		40-yr Rehab (Lane Replacement)																10-yr CapM (Conc Pvmt Rehab #3*)				5-yr CapM (Conc Pvmt Rehab #2*)		5-yr CapM (Conc Pvmt Rehab #1*)	
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	40	2,540															10	2,229			5	4,393	5	4,393
Rigid Crack, Seat, w/ 0.45' HMA Overlay	20	1,2,3		Year of Action		0						18		23		28		33				42		49					
				Activity Description		20-yr Rehab (CSOL)						5-yr CapM (0.10' HMA Overlay)		5-yr CapM (0.15' HMA Overlay +2% Digout)		5-yr CapM (0.10' HMA Overlay)		10-yr Rehab (0.40' HMA Overlay +5% Digout)				5-yr CapM (0.15' HMA Overlay +2% Digout)		Reconst					
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	18	3,860					5	0	5	0	5	0	9	3,737			7	813						
Rigid Crack, Seat, w/ 0.35' HMA Overlay	10	1,2,3		Year of Action		0		9		14		19		24				33				40							
				Activity Description		10-yr Rehab (CSOL)		5-yr CapM (0.10' HMA Overlay)		5-yr CapM (0.15' HMA Overlay +2% Digout)		5-yr CapM (0.10' HMA Overlay)		10-yr Rehab (0.35' HMA Overlay +5% Digout)				5-yr CapM (0.15' HMA Overlay +2% Digout)				Reconst							
				Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	9	0	5	0	5	0	5	0	9	3,737			7	813										

Notes:

(1) Conc Pvmt Rehab C involves pavement grinding, minor slab replacement, spall repair, & joint seal repair. It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is 2% or less.

(2) Conc Pvmt Rehab B involves pavement grinding, moderate slab replacement, spall repair, & joint seal repair. It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is between 2 and 5%.

(3) Conc Pvmt Rehab A involves pavement grinding, significant slab replacement, spall repair, & joint seal repair. It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is greater than or equal to 5% and less than or equal to 7%. For greater than 7%, the project should be scoped and analyzed as a roadway rehabilitation project.

(4) Select the roadway rehabilitation option found in this table that would best represent how the project will be rehabilitated in the future.

APPENDIX 5: TRAFFIC INPUTS ESTIMATION

A. Free Flow Capacity

The procedure for estimating the "Free Flow Capacity (vphpl)" is as follows:

(*Assume*: standard lane and shoulder widths)

1) Select an *E* value [passenger car equivalent factor (passenger cars/heavy vehicle) corresponding to the project terrain from Table 20

Table 15. Passenger Car Equivalent Factors

	Type of Terrain		
	Level	**Rolling**	**Mountainous**
E	1.5	2.5	4.5

2) Use Equation A5-1 to calculate "Free Flow Capacity" in terms of vphpl (vehicle per hour per lane):

$$FC = \frac{F \times 100}{[(100 + P \times (E - 1)]} \qquad \text{(Equation A5-1)}$$

where

FC = Free Flow Capacity (vphpl)

F = roadway capacity (passenger car per hour per lane)

= 1,700 pcphpl for two-lane highways

= 2,300 pcphpl for multi-lane highways

P = percentage of heavy vehicles (i.e., "Total Trucks %" at the project location)

E= passenger car equivalent (passenger cars/heavy vehicle).

B. Queue Dissipation Capacity

The procedure for estimating the "Queue Dissipation Capacity (vphpl)" is as follows:

(*Assume*: standard lane and shoulder widths)

1) Select an *E* value [passenger car equivalent factor (passenger cars/heavy vehicle) corresponding to a type of terrain at the project location from Table 15

2) Use Equation A5-2 to calculate "Queue Dissipation Capacity" in terms of vphpl (vehicle per hour per lane):

$$QC = \frac{Q \times 100}{[(100 + P \times (E - 1)]} \qquad \text{(Equation A5-2)}$$

where

QC = Queue Dissipation Capacity (vphpl)

Q = base capacity (passenger car per hour per lane)

= 1,800 pcphpl for both single-lane and multi-lane highways

P = percentage of heavy vehicles (i.e., "Total Trucks %" at the project location)

E= passenger car equivalent (passenger cars/heavy vehicle).

C. Maximum AADT (total for both directions)

The procedure for estimating the "Maximum AADT (total for both directions)" is as follows:

1) Select an E value [passenger car equivalent factor (passenger cars/heavy vehicle) corresponding to a type of terrain at the project location from Table 15

2) Use Equation A5-3 to calculate "Maximum AADT (total for both directions)"

$$AADT_{\max} = \frac{M \times N \times 100}{[(100 + P \times (E - 1)]} \qquad \text{(Equation A5-3)}$$

where

$AADT_{max}$ = Maximum AADT (total for both directions)

M =

M = 43,000 for two-lane highways or 57,000 for multi-lane highways

N = number of lanes (total for both directions)

P = percentage of heavy vehicles (i.e., “Total Trucks %” at the project location)

E = passenger car equivalent (passenger cars/heavy vehicle).

D. Work Zone Capacity

The procedure for estimating the “Work Zone Capacity (vphpl)” is as follows:

(*Assume*: standard lane and shoulder widths)

1) Select an E value [passenger car equivalent factor (passenger cars/heavy vehicle) corresponding to a type of terrain at the project location from Table 11.

2) Use Equation A5-4 to calculate “Work Zone Capacity” in terms of vphpl (vehicle per hour per lane):

$$WC = \frac{W \times 100}{[(100 + P \times (E - 1)]} \qquad \text{(Equation A5-4)}$$

where

WC = Work Zone Capacity (vphpl)

W = base work zone capacity (passenger car per hour per lane)

W = 1,100 pcphpl for two-lane highways

= 1,600 pcphpl for multi-lane highways

P = percentage of heavy vehicles (i.e., “Total Trucks %” at the project location)

E= passenger car equivalent (passenger cars/heavy vehicle).

E. Maximum Queue Length Estimation

The maximum number of queued vehicles during which the work zone is in effect. It is estimated by using the traffic demand-capacity model, as shown in Figure 18. When demand exceeds capacity, the queue starts to build up. The maximum number of queued vehicles is measured where the difference between the demand curve and the capacity curve is the greatest. Then the maximum queue length can be obtained by multiplying the maximum number of queued vehicles by the average vehicle length (i.e., 40 feet).

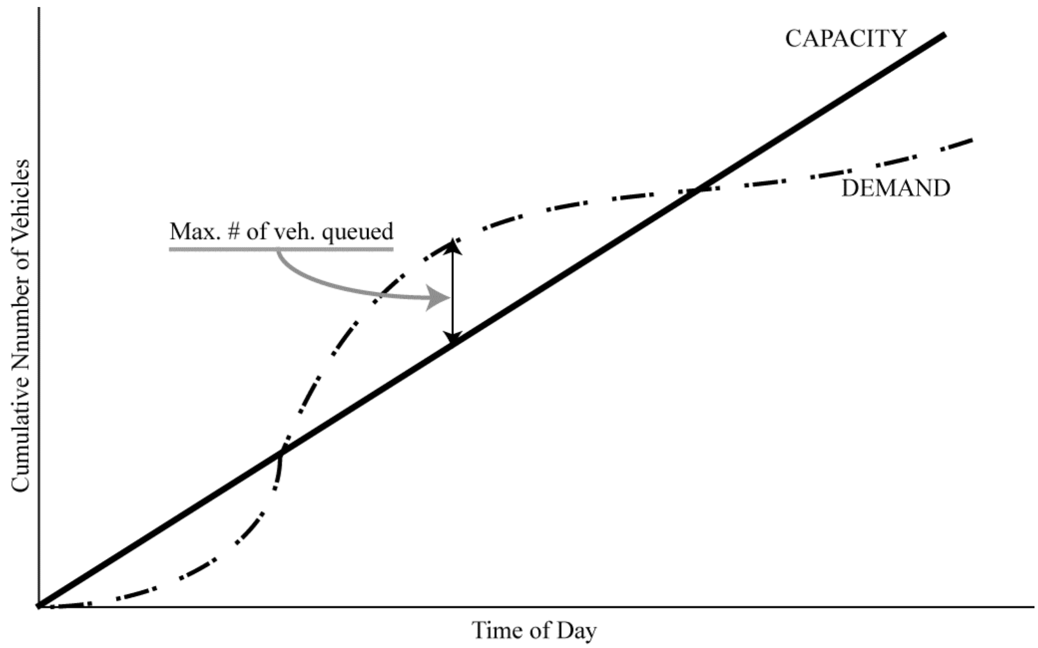


Figure 16. Traffic Demand-Capacity Model

<u>Example:</u>

<u>Maximum Queue Length Estimation</u>

During construction on a three-lane urban freeway section, one lane will be closed and two lanes will be open. The work zone capacity is assumed to be 1,600 passenger cars per hour per lane (pcphp). The hourly traffic demands, expressed in vehicles per hour (vph), are assumed to be those shown in the second column in Table 16. Ten percent of the traffic volume is assumed to be occupied by single-unit and combination trucks. The procedure for estimating the maximum queue length is:

1) *The hourly passenger car capacity of one lane (1,600 pcphpl) of the work zone is converted to the hourly vehicular capacity of one lane [1,524 vphpl (vehicles per hour per lane)] of the work zone using Equation A5-4.*

Table 16. Maximum Queue Length Estimation

Hour	Volume (vph)	Capacity (pcphpl)	Capacity (vphpl)	No. of lanes open	Capacity (vph)	Queued veh.	
1	340	1,600	1,524	2	3,048	0	
2	350	1,600	1,524	2	3,048	0	
3	350	1,600	1,524	2	3,048	0	
4	400	1,600	1,524	2	3,048	0	
5	800	1,600	1,524	2	3,048	0	
6	1,200	1,600	1,524	2	3,048	0	
7	3,000	1,600	1,524	2	3,048	0	
8	3,400	1,600	1,524	2	3,048	352	
9	3,600	1,600	1,524	2	3,048	904	
10	3,000	1,600	1,524	2	3,048	856	
11	1,800	1,600	1,524	2	3,048	0	
12	1,300	1,600	1,524	2	3,048	0	
13	1,200	1,600	1,524	2	3,048	0	
14	1,000	1,600	1,524	2	3,048	0	
15	1,200	1,600	1,524	2	3,048	0	
16	1,900	1,600	1,524	2	3,048	0	
17	3,400	1,600	1,524	2	3,048	352	
18	3,650	1,600	1,524	2	3,048	954	
19	2,400	1,600	1,524	2	3,048	306	
20	1,000	1,600	1,524	2	3,048	0	
21	800	1,600	1,524	2	3,048	0	
22	760	1,600	1,524	2	3,048	0	
23	300	1,600	1,524	2	3,048	0	
24	300	1,600	1,524	2	3,048	0	
			Max. queued veh.			954	
			Max. queued veh. on 3 lanes			318	
			Average vehicle length			40	ft
			Max. queue length			12,720	ft
						2.41	mi

2) *As shown in Table 12, the queue starts at 8 AM when the traffic demand (3,400 vph) exceeds the work zone capacity (3,048 vph) and dissipates at 11 AM when the sum of the hourly demand (1,800 vph) and the number (856) of queued vehicles becomes less than the work zone capacity. The queue starts again at 5 PM when the traffic demand (3,400 vph) exceeds the work zone capacity (3,048 vph).*

3) *The maximum number of queued vehicles is 954 at 6 PM when the number of the queued vehicles is the greatest. The maximum number of queued vehicles per lane is 318 (954*

vehicles divided by 3 lanes). Thus, the maximum queue length from the work zone operation is estimated at 2.41 miles (318 vehicles multiplied by 40 ft average vehicle length).

APPENDIX 6:

ALTERNATE PROCEDURE FOR CALCULATING CONSTRUCTION YEAR AADT

The following steps describe how to get a construction year AADT:

1) Go to the Division of Traffic Operations website (http://www.dot.ca.gov/hq/traffops/saferesr/trafdata/index.htm). Download the most current year AADT data available (such as "2005AADT" in excel file form). Find "Back AADT" and "Ahead AADT" numbers at the project location and add those two numbers to get the total AADT for both directions in the most current year.

2) Contact the Division of Traffic System Information for the "Annual Growth Rate of Traffic" or AADT values (in the most current and future years) expected at the project location. An approximate "Annual Growth Rate of Traffic" can be estimated with the available AADT values using Equation 2 below:

$$A = \left(\frac{F\_AADT}{M\_AADT}\right)^{\left(\frac{1}{FY-MY}\right)} \qquad \text{(Equation A6-1)}$$

where

A = Annual Growth Rate of Traffic

F_AADT = Future Year AADT (total for both directions)

M_AADT = Most Current Year AADT (total for both directions)

FY = Future Year in which AADT is available

MY = Most Current Year in which AADT is available.

Example:

Given:

Future Year AADT (total for both directions) = 18,000 (year 2025)

Most Current Year AADT (total for both directions) = 9,800 (year 2005)

The Annual Growth Rate of Traffic is

$$\left(\frac{18{,}000}{9{,}800}\right)^{\left(\frac{1}{2025-2005}\right)} = 1.03\%$$

Use the following equation to calculate the AADT total for both directions in the initial construction year or the beginning year of the analysis period:

$$I\_AADT = M\_AADT \times \left(1+\frac{A}{100}\right)^{(IY-MY)} \quad \text{(Equation A6-2)}$$

where

I_AADT = Initial Construction Year AADT (total for both directions)

M_AADT = Most Current Year AADT (total for both directions)

A = Annual Growth Rate of Traffic (%)

IY = Initial Construction Year (same as the first year of the analysis period)

MY = Most Current Year in which AADT is available.

$$(9{,}800) \times \left(1+\frac{1.03}{100}\right)^{(2007-2005)} = 10{,}002$$

APPENDIX 7: WEEKEND TRAFFIC HOURLY DISTRIBUTION

Hour	AADT Rural (%)	Inbound Rural (%)	Outbound Rural (%)	AADT Urban (%)	Inbound Urban (%)	Outbound Urban (%)
0 - 1	1.91	47.6	52.4	1.8	47.7	52.3
1 - 2	1.61	49.5	50.5	1.3	47.8	52.2
2 - 3	1.32	49.0	51.0	0.9	46.5	53.5
3 - 4	1.52	54.9	45.1	0.8	52.2	47.8
4 - 5	1.64	54.9	45.1	0.9	56.3	43.7
5 - 6	2.13	53.0	47.0	1.5	55.5	44.5
6 - 7	2.86	50.8	49.2	2.4	53.2	46.8
7 - 8	3.58	50.4	49.6	3.4	51.6	48.4
8 - 9	4.38	50.0	50.0	4.6	50.9	49.1
9 - 10	5.22	50.7	49.3	5.5	50.2	49.8
10 - 11	5.96	51.3	48.7	6.2	49.8	50.2
11 - 12	6.46	50.6	49.4	6.7	49.1	50.9
12 - 13	6.58	50.9	49.1	7.0	48.7	51.3
13 - 14	6.58	51.3	48.7	7.0	48.5	51.5
14 - 15	6.66	52.4	47.6	7.1	47.9	52.1
15 - 16	6.89	53.1	46.9	7.0	48.1	51.9
16 - 17	6.73	52.9	47.1	6.7	47.9	52.1
17 - 18	6.21	52.6	47.4	6.3	48.4	51.6
18 - 19	5.54	51.5	48.5	5.7	48.4	51.6
19 - 20	4.77	50.7	49.3	5.0	48.9	51.1
20 - 21	4.02	51.4	48.6	4.2	48.8	51.2
21 - 22	3.28	51.4	48.6	3.5	49.5	50.5
22 - 23	2.60	50.7	49.3	2.7	49.6	50.4
23 - 24	1.54	48.6	51.4	1.6	49.8	50.2
	100.0			100.0		